

UK6 FB 80009

UK6 FB80 D09

Freshwater Biological Association

Occasional Publication No.9

PETROLEUM HYDROCARBONS IN FRESH WATERS : A Preliminary

Desk Study and Bibliography / Jones, J.G; Horne, J.E.M;

Moorhouse, Pamela; Powell, Deborah L 1980.

# PETROLEUM HYDROCARBONS IN FRESH WATERS

A Preliminary Desk Study and Bibliography

J. G. Jones, J. E. M. Horne,  
Pamela Moorhouse & Deborah L. Powell



**Earth Sciences Library**

OCCASIONAL PUBLICATION No. 9



Digitized by the Internet Archive  
in 2025 with funding from  
University of Toronto

<https://archive.org/details/31761056890569>

**IN MEMORY OF  
DR. JUDITH F. M. HOENIGER  
1987**

*Judith Hoenger*

A preliminary desk study on  
PETROLEUM HYDROCARBONS  
IN FRESH WATERS

by

J. Gwynfryn Jones, J.E.M. Horne,  
Pamela Moorhouse & Deborah L. Powell.

*Freshwater Biological Association*

*Occasional Publication No. 9*

1980

CONTENTS

|                                                       | Page |
|-------------------------------------------------------|------|
| 1. INTRODUCTION                                       | 3    |
| 2. CLASSIFICATION OF THE REFERENCES                   | 6    |
| A. Ecological and toxic effects, uptake, accumulation | 6    |
| B. Microbial utilization, degradation                 | 11   |
| C. General occurrence, properties                     | 12   |
| D. Methods, detection and analysis                    | 13   |
| E. Causes, sources                                    | 16   |
| F. Treatment                                          | 16   |
| G. Carcinogenesis                                     | 16   |
| H. Soil                                               | 17   |
| 3. CONCLUSIONS                                        | 18   |
| 4. BIBLIOGRAPHY                                       | 19   |
| 5. ACKNOWLEDGEMENTS                                   | 46   |
| 6. AUTHOR INDEX                                       | 47   |



## 1. INTRODUCTION

To understand the effects of petroleum hydrocarbons in fresh waters, we require information on their toxicity, biodegradability and concentration. To obtain this information a survey of the literature was carried out, supplemented by a selective search on hydrocarbons in the marine environment, for purposes of comparison. Our aim has been to determine the major inputs of these hydrocarbons, their accumulation, effects and fate in fresh waters, as revealed by the published literature. This information is summarized in Tables 3 - 10 below.

The search was confined to the period 1965 - 1978, since there was little significant study of hydrocarbons in fresh waters before then, and the general field of hydrocarbon microbiology prior to 1965 is covered by several excellent reviews.\* Since 1965 a number of large oil-spills have resulted in a rapid growth of the literature, and recent work has produced a better understanding of the biochemical mechanisms of oil decomposition.

The main bibliographic sources used in the search were as follows:

*Aquatic Biology Abstracts*, Vols 2-3, 1970-1971, continued as  
*Aquatic Sciences and Fisheries Abstracts*, Vols 1-8, 1971-1978.

*Biological Abstracts*, Vols 46-66, 1965-1978.

*Bioresearch Index*, Vols 10-14, 1974-1978.

*International Biodeterioration Bulletin Reference Index*

*Supplement*, Vols 5-8, 1969-1972, continued as

*Biodeterioration Research Titles*, Vols 9-14, 1973-1978.

*Pollution Abstracts*, Vols 1-9, 1970-1978.

*Water Pollution Abstracts*, Vols 38-46, 1965-1973, continued as  
*WRC Information*, Vols 1-5, 1974-1978.

*A bibliography on marine and estuarine oil pollution*, Suppl. 2,  
by D.S. Moulder & A. Varley (1978). Plymouth, Marine  
Biological Association of the U.K.

---

\* e.g. Davies, J.B. (1967). *Petroleum microbiology*. Amsterdam, Elsevier. 604pp.

Van der Linden, A.C. & Thijsse, G.J.E. (1965). The mechanisms of microbial oxidation of petroleum hydrocarbons. *Adv. Enzymol.* 27, 496-546.

The terms used for searching included: hydrocarbons; petroleum; petrochemicals; diesel fuel; oil; gasoline; benz-pyrene; bacteria; micro-organisms; pollution.

About 800 references were retrieved, of which 390 were examined in some depth; these latter form the bibliography which follows\*. The final selection was based on relevance, originality, scientific quality and language - we were unable to obtain translations of Russian and other papers in the time available.

Of the papers retrieved, 82% were found in one bibliographic source only. A breakdown of information by environment is shown in Table 1, and by geographical origin in Table 2; these tables should be interpreted in accordance with the selective nature of the search as described above, and the somewhat random inclusion of certain material. It is unlikely, for example, that North America has produced no papers on carcinogenesis, and the results merely reflect that only a few papers, mainly Russian in origin, were chosen for inclusion. Figures for the relatively small British contributions to work on microbial decomposition and environmental analysis (Table 2, B,C) may be considered as more reliable since the sample sizes were much larger.

\* In a few cases only the abstract was seen; in consequence, bibliographic details may be incomplete.

Table 1 Breakdown of references by environment

| Reference classification                             | Environment (%) |        |                            |    |
|------------------------------------------------------|-----------------|--------|----------------------------|----|
|                                                      | Freshwater      | Marine | General Laboratory aquatic |    |
| A. Effects, Uptake, Accumulation<br>(155 papers)     | 28*             | 29     | 10                         | 33 |
| B. Microbial Utilization, Degradation<br>(91 papers) | 33              | 36     | 4                          | 27 |
| C. General Occurrence, Properties<br>(36 papers)     | 76              | 3      | 15                         | 6  |
| E. Causes, Sources<br>(37 papers)                    | 89              | 8      | 3                          | 0  |
| Total Papers                                         | 41              | 23     | 7.5<br>(+ 3.5 in soil)     | 25 |

\* figures are percentages, for each environment, of the papers retrieved under each reference class. Final row is environmental breakdown for all the papers in these classes, including those on soil.

Table 2 Breakdown of references by geographical origin

| Reference classification                             | Origin  |                       |            |       | Total |
|------------------------------------------------------|---------|-----------------------|------------|-------|-------|
|                                                      | British | European <sup>1</sup> | N.American | Other |       |
| A. Effects, Uptake, Accumulation<br>(155 papers)     | 12*     | 11                    | 72         | 5     | 40    |
| B. Microbial Utilization, Degradation<br>(91 papers) | 7       | 16                    | 73         | 4     | 23    |
| C. General Occurrence, Properties<br>(36 papers)     | 6       | 40                    | 43         | 11    | 9     |
| D. Methods (38 papers)                               | 12      | 18                    | 70         | 0     | 10    |
| E. Causes, Sources (37 papers)                       | 22      | 31                    | 44         | 3     | 10    |
| F. Treatment (15 papers)                             | 6       | 47                    | 47         | 0     | 4     |
| G. Carcinogenesis (5 papers)                         | 20      | 80                    | 0          | 0     | 1     |
| H. Soil (13 papers)                                  | 18      | 45                    | 37         | 0     | 3     |
| Total                                                | 11.5    | 21                    | 63         | 4.5   | 100   |

\* figures are percentages of the papers retrieved under each reference class. The final row is the geographical breakdown for all the papers abstracted in this study. The final column is the percentage breakdown of all papers abstracted by class.

<sup>1</sup> Including USSR

## 2. CLASSIFICATION OF THE REFERENCES

References are classified and the bibliography arranged in subject groups as follows. In each group, references are in alphabetic order of authors and are identified by the section letter and a serial number.

- A. *Ecological and toxic effects, uptake, accumulation*: including toxicity tests, observed uptake in all organisms and accumulation down the food chain.
- B. *Microbial utilization, degradation*: laboratory and environmental studies.
- C. *General occurrence, properties*: including analyses of samples from natural and man-made environments.
- D. *Methods, detection and analysis*: the most commonly used methods of analysis.
- E. *Causes, sources*: details of the inputs of petroleum hydrocarbons to the environment.
- F. *Treatment*: in the environment and in effluent plants.
- G. *Carcinogenesis*: this section (along with F) was not within the remit of the contract but the most relevant references abstracted were retained.
- H. *Soil*: not a complete survey, but selected references were included to obtain an understanding of microbial action on hydrocarbons before entry into water courses.

### A. ECOLOGICAL AND TOXIC EFFECTS, UPTAKE, ACCUMULATION

This section is mainly concerned with the effects of petroleum hydrocarbons on organisms. Detailed reviews on this subject are to be found in A 56, 74, 91, 96, 99, 101, 104, 110, 111, 117, 141 and 150. The literature on the harmful effects on macrobiota is summarized in Table 3, and general measurements of tissue concentrations not necessarily associated with damage are shown in Table 4. Hydrocarbons may stimulate or inhibit microorganisms, depending on the concentration and the species involved. A summary of the papers dealing with these effects is found in Table 5, and the more general environmental studies,



classified by the communities and organisms involved, are presented in Table 6.

*Notes*

- a. Units of concentration are variable and their meaning is not always clear. The units used by the original author are presented here, with no attempt at interpretation. No attempt is made to differentiate studies on single hydrocarbons or petroleum mixtures.
- b. A large proportion of the work has been devoted to higher animals, especially fish. The adverse effects noted include the occurrence of tainting. Work particularly devoted to the effect of outboard engine exhaust products includes A 58, 59 and 64.
- c. Microorganisms may be stimulated by hydrocarbons and can play a part in their decomposition. Mutagenesis is amongst the harmful effects noted (A 113).
- d. Much of the work on microorganisms has been done with pure cultures or pure hydrocarbons.
- e. The range of toxic concentrations, in all cases, is large.
- f. The possible excretion of polluting hydrocarbons by macrobiota requires further consideration (A 27, 133).

Table 3 Concentration ranges of hydrocarbons  
observed to affect biota adversely

| <i>Organisms</i> | <i>Concentration range</i>   |                       | <i>References</i><br>A                                                             |
|------------------|------------------------------|-----------------------|------------------------------------------------------------------------------------|
|                  | <i>In organism</i>           | <i>In environment</i> |                                                                                    |
| Fish             | 0.7 - 94 ppm                 | 0.03 - 3500 ppm       | 2,3,8,19,28,34,<br>35,40,41,68,82,<br>83,86,87,88,92,<br>93,94,114,115,<br>116,139 |
| Decapods         | 0.14 - 1.6 ppm               | 0.95 - 1000 ppm       | 3,17,137                                                                           |
| Amphipods        | 0.3 - 0.4 ppm                | 0.1 - 4.2 ppm         | 3,17,44                                                                            |
| Polychaetes      | 0.3 - 20 ppm                 | -                     | 3,120,121                                                                          |
| Insects          | -                            | 14 - 59 ppm           | 12,13,14                                                                           |
| Shellfish        | 10 ppm                       | 0.05 - 17 ppm         | 15,24                                                                              |
| Birds            | 12.5 - 50 ppm<br>(oral dose) |                       | 29,30                                                                              |

Table 4 Concentration ranges of hydrocarbons  
observed in biota

| <i>Organisms</i>      | <i>Concentration range</i>      | <i>References</i> |
|-----------------------|---------------------------------|-------------------|
|                       |                                 | A                 |
| Fish                  | 0.1 - 1000 ppm                  | 1,4,27,106,107    |
| Shellfish             | 0.8 - 69 ppm                    | 4,98,100          |
| Amphipods             | 43 ppm                          | 4                 |
| Ducks                 |                                 | 72,73             |
| Benthic invertebrates | 0.02 - 210 $\mu\text{g g}^{-1}$ | 134,138           |
| Algae                 | 15 - 30 $\mu\text{g g}^{-1}$    | 140               |

Table 5 The effect of petroleum hydrocarbons on microorganisms

| Organism and effect<br>(see footnote) | Hydrocarbon concentration                            | References<br>A |
|---------------------------------------|------------------------------------------------------|-----------------|
| B+, Ac, Pc                            | 0.1 - 1.0 ml ml <sup>-1</sup>                        | 5               |
| A+                                    | 10 - 30 µg l <sup>-1</sup>                           | 7               |
| A-                                    | 0.038 - 0.124 mg l <sup>-1</sup>                     | 9,16            |
| A-                                    | > 0.001 ppm                                          | 18              |
| B-                                    | < 2% saturation                                      | 22              |
| B-                                    | > 1.2 mg l <sup>-1</sup>                             | 23              |
| A-                                    | 0.1 - 10 ml l <sup>-1</sup>                          | 31              |
| A-                                    | 0.1 - 10%                                            | 33              |
| Bo/-, Ao/-                            | -                                                    | 36              |
| A+/-                                  | 10 <sup>2</sup> - 10 <sup>4</sup> µg l <sup>-1</sup> | 39              |
| B+                                    | 80 ppb                                               | 53              |
| B-                                    | > 300 ppb                                            | 53              |
| B+                                    | -                                                    | 55              |
| A-                                    | 33 - 1780 ppm                                        | 61,62           |
| A-                                    | 3 - 500 ppm                                          | 63              |
| A-                                    | 0.1 - 1.0 g l <sup>-1</sup>                          | 66              |
| A+                                    | < 5 ppm                                              | 69              |
| A-                                    | 5 - 700 mg l <sup>-1</sup>                           | 70              |
| B+                                    | 1000 ppm                                             | 90              |
| A-                                    | -                                                    | 103             |
| A+/-                                  | 5 - 500 µg l <sup>-1</sup>                           | 112             |
| A-                                    | 10 - 100 mg l <sup>-1</sup>                          | 128-132,E3      |
| B+, Fo                                | -                                                    | 146             |
| B-                                    | -                                                    | 147             |
| A-                                    | 5 ppm                                                | 151-153         |

Abbreviations : First letter: A = algae, B = bacteria, P = protozoa,  
F = fungi

Second letter: + = stimulation, - = inhibition,  
+/- both effects depending on concentration,  
o = no change, c = change in species  
composition.

Table 6 General environmental studies

| Environment | Community - organisms   |                                       | Effects                      | References |
|-------------|-------------------------|---------------------------------------|------------------------------|------------|
| A           |                         |                                       |                              |            |
| Stream      | Benthos                 | algae                                 | species change               | 10         |
|             | "                       | fauna                                 | lethal                       | 21         |
|             | "                       | algae                                 | harmful                      | 25         |
|             |                         | macroinvertebrates                    | toxic                        | 54         |
|             | "                       | "                                     | lethal                       | 81         |
|             | "                       | "                                     | reduction in numbers         | 97         |
| River       | Benthos                 | macrofauna, bacteria                  | some toxicity,               | 84,85      |
|             | "                       | chironomids                           | effect species-<br>dependent | 118        |
| Lake        | Benthos                 | chironomids                           | lethal                       | 11         |
|             | "                       | littoral                              | lethal                       | 126,127    |
|             | "                       | invertebrates                         | increase in numbers          | 126,127    |
|             |                         | sublittoral inverte-<br>brates, algae |                              |            |
| Pond        | Plankton                | algae                                 | decreased efficiency         | 26         |
|             | "                       | "                                     | no effect                    | 50         |
|             | Benthos                 | "                                     | inhibition                   | 50         |
|             | "                       | insects                               | lethal                       | 60         |
|             | Plankton                | algae, bacteria                       | stimulation                  | 124        |
|             | Plankton                | algae                                 | inhibition                   | 143        |
| Marine      | Plankton                | algae                                 | inhibition                   | 80         |
|             | General flora and fauna |                                       | lethal                       | 89         |
| Saltmarsh   | Higher plants           |                                       | harmful                      | 6, 20      |
|             | Bacteria                |                                       | increase in numbers          | 42         |



## B. MICROBIAL UTILIZATION, DEGRADATION

The papers abstracted in this section are classified in Table 7.

### Notes

- a. The relative importance of bacteria in aquatic decomposition processes is in sharp contrast to that observed in soil where the fungal contribution is greater.
- b. Much of the degradation work is laboratory-based and reliable estimates of rates of decomposition in the field are relatively few.
- c. There is mounting evidence of nutrient limitation of hydrocarbon decomposition in water (B 3, 6, 53, 85, 86).
- d. Whereas the weight of evidence indicates preferential utilization of certain hydrocarbons, some studies (B 3, 59) have shown all fractions to be decomposed at similar rates. Growth on a single hydrocarbon is not a good indication of its utilization in a mixture (B 17).
- e. There is evidence both of success (B 54, 66, 68) and failure (B 84, A 135) in attempts to obtain anaerobic decomposition of hydrocarbons in the presence of alternative electron transport acceptors.
- f. Weathering may remove inhibitory substances from oil (B 2) but residual resinous tars may be more refractory than the volatile fraction (B 18).
- g. It is of interest that the latest text in this subject area (B 13) contains no information on the effect of hydrocarbons on the micro-biology of fresh waters.

Table 7 Classification of papers on microbial utilization, degradation  
Section B \*

|          | <i>Reviews</i>                              | <i>Laboratory studies</i>                                                                | <i>Field studies</i>                                           |
|----------|---------------------------------------------|------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| Bacteria | 21,22,34,35,36                              | 2,4,7,15,18,25,27,44,<br>45,53,54,58,59,63,66,<br>68,70,71,72,76,79,80,<br>81,83,90,A144 | 3,9,32,33,49,<br>50,52,56,57,<br>60,69,73,74,<br>84,85,86,A125 |
| Fungi    | 1                                           | 17,26,55                                                                                 | 9,14,74                                                        |
| General  | 10,12,13,16,31,<br>38,40,41,46,48,<br>67,88 | 11,23,24,39,61,64,65,<br>78,82                                                           | 8,29,30,37,42,<br>62,64,65                                     |

\* Materials from other sections have letter prefix

### C. GENERAL OCCURRENCE, PROPERTIES

A useful general review on allochthonous and autochthonous hydrocarbons in the aquatic environment is provided in C 3, and D 25 lists the hydrocarbons isolated from petroleum in recent analyses. A survey which concentrated on polynuclear aromatics (C 5) also included the results of toxicity tests on a range of petroleum hydrocarbons. Some of the data on observed concentration ranges are summarized in Table 8. Not all the references cited contain quantitative information. The potential carcinogenicity of polynuclear aromatic hydrocarbons (PAH) has undoubtedly contributed to the emphasis placed on this group. Baseline values for PAH and threshold odour concentrations of a number of compounds are published (E 4, C 19). The increase in concentration with proximity to centres of population suggests that combustion of fossil fuels may be the main source of PAH (C 12). The concentration ranges of the hydrocarbons in Table 8 overlap those shown to exert an adverse effect on macrobiota (Table 3) and microorganisms (Table 5).

Table 8      Some analyses of hydrocarbons in freshwaters

| <i>Hydrocarbon</i>   | <i>Concentration range</i>          | <i>References</i> |
|----------------------|-------------------------------------|-------------------|
|                      |                                     | C                 |
| Aliphatic            | 1400 $\mu\text{g g}^{-1}$ *         | 33                |
| Polynuclear aromatic | $10^{-5}$ - 13 $\mu\text{g l}^{-1}$ | 1,7,10,18,28      |
| Crude/fuel oil       | 0.02 - 1.42 $\text{mg l}^{-1}$      | 8,21,22,23,24     |
| Petroleum/products   | 0.15 - 0.8 $\text{mg l}^{-1}$       | 16,25             |
| Total hydrocarbons   | 50 - 1500 $\mu\text{g g}^{-1}$      | 6,9,26,29,32      |
|                      | 1 - 5.5 $\mu\text{g l}^{-1}$        | 13,14,20,A33      |

\* analyses of sediments are calculated on a dry weight basis

#### D. METHODS, DETECTION AND ANALYSIS

Although not primarily concerned with methodology this desk study retrieved several papers concerned with analytical procedures. These are summarized in Table 9. Further details of methodology, particularly with regard to changes in composition due to microbial activity are to be found in references cited in Section B. Gas chromatographic procedures have been used extensively and these are coupled with analysis of mass spectra when detailed analysis is required.

Table 9      Methods used for analysis of petroleum hydrocarbons  
                 in the natural environment

| <i>Method</i>                       | <i>References D</i>                           |
|-------------------------------------|-----------------------------------------------|
| Gravimetric, physico-chemical       | 6,7,11,14,16,20,27,31                         |
| Resin sorption                      | 1,34                                          |
| Paper chromatography                | 7,27                                          |
| Column chromatography               | 1,9,15,23,35,38                               |
| Thin-layer chromatography           | 1,7,16,33,37                                  |
| High pressure liquid chromatography | 3,12,30                                       |
| Gas chromatography                  | 1,4,5,6,7,9,10,15,17,18,20,22,<br>24,27,29,32 |
| Visible and U.V. spectroscopy       | 7,8                                           |
| Infra-red spectroscopy              | 2,7,14,18,19,20,26,27,28                      |
| Fluorescence spectroscopy           | 2,3,7,13,27,35,38                             |
| Mass spectrometry                   | 8,9,15                                        |

Table 10 Major sources of petroleum hydrocarbons in aquatic environments

| Environment             | Assessment of pollution sources <sup>1</sup>                                                                                                  | References <sup>2</sup> |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
|                         |                                                                                                                                               | E                       |
| Water supplies          | Largely from oil pipelines                                                                                                                    | 1                       |
| Subsurface/ground water | Waste dumping, settling tanks, pipelines                                                                                                      | 2,5,27,31               |
| Lakes/Reservoirs        | a) Lake Champlain: 38% run off, leaks, dumping; 6% shipping traffic; 56% outboard motor boats                                                 | A109                    |
|                         | b) Lake Washington: 70% river and stormwater damage; 11% bridge runoff; 10% dustfall; 3% rainfall; 6% streamflow; < 0.4% outboard motor boats | 34,35                   |
|                         | c) 50% of pollution due to heating oil (gas oil) or diesel oil from road vehicles                                                             | D37                     |
|                         | d) Fuel oil from machinery, storm-water surface runoff                                                                                        | 7                       |
|                         | e) Outboard motor exhaust                                                                                                                     | 9,11                    |
|                         | f) Industry, navigation, underwater pipelines                                                                                                 | 22,23                   |
| General inland waters   | a) 45% storage, pipelines; 5% tanker deliveries; 7% garages, boats etc; 8% road tanker accidents; 35% general incidents                       | 29,C30                  |
|                         | b) Tipping, blockages, seepage, overfilling tanks, garages, accidents                                                                         | 25,A32                  |
|                         | c) Mainly heating and diesel fuel; sewage effluents and surface runoff may have adverse long term effects                                     | 13                      |
|                         | d) Storm water                                                                                                                                | 14                      |
|                         | e) Outboard motors                                                                                                                            | 15,19,28                |
|                         | f) PAH, mainly from airborne combustion products                                                                                              | 16                      |
|                         | g) Industry and distribution                                                                                                                  | 20,26                   |



Table 10 (continued)

| Environment | Assessment of pollution sources <sup>1</sup>                                                                                                                                                                                                         | References <sup>2</sup> |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
|             |                                                                                                                                                                                                                                                      | E                       |
| Rivers      | a) 30% domestic and industrial heating accidents during filling and storage; 10% pipelines, 10% waste oil disposal; 11% engines (including service stations, depots, airfields); 5% tanker accidents; 23% other traced sources; 11% untraced sources | 23                      |
|             | b) Run off                                                                                                                                                                                                                                           | 17                      |
|             | c) Oil refinery and petrochemical wastes                                                                                                                                                                                                             | 24                      |
|             | d) Municipal wastewater, secondary treatment plant                                                                                                                                                                                                   | 32                      |
| Effluents   | Up to 20 mg l <sup>-1</sup> petroleum hydrocarbons, oil and grease                                                                                                                                                                                   | 12,C15,C34              |
| Marine      | On shore sources: 41% municipal wastes, non-refining industrial wastes, urban and river runoff                                                                                                                                                       | 6,36,A56                |
| Air         | Municipal waste combustion                                                                                                                                                                                                                           | 8                       |

<sup>1</sup> Many studies were non-quantitative and the method of assessment must be obtained from the reference

<sup>2</sup> References from sections other than E have letter prefix

## E. CAUSES, SOURCES

The assessment of sources of pollution has been largely non-quantitative. In some instances the relative importance of various sources has been estimated and these values are included in Table 10. In spite of the qualitative nature of much of the information the following points were considered to be of interest:

- a. The relative importance of sources of lake pollution will vary enormously with lake usage (cf. results from Lake Champlain and Lake Washington in Table 10).
- b. Many of the surveys have been concerned with catastrophic incidents. Chronic low-level pollution may be overlooked.
- c. Although there have been several papers on the effects of outboard motors, many have provided only qualitative information. There appears to be some agreement that two-stroke lubricating oil is a major source of pollution (this would be reduced if four-stroke engines were used). Fish tainting has been observed at a boating density equivalent to consumptions of 8 volumes of outboard motor fuel per million volumes of lake water (E 18).

## F. TREATMENT

Of the 15 references retrieved under this subject heading the majority were concerned with cleaning up catastrophic spills by collection, burning off or emulsification (F 2, 3, 7 and 9). The detention period of conventional sewage plants is too short for effective treatment (F 10) and alternative procedures must be adopted. Some success has been achieved with graphite and other sorbent filter processes (F 4, 5 and 11) although chlorination can modify polycyclic aromatic hydrocarbons (F 6). Treatment of contaminated groundwater is a difficult process (F 14, 15) and has not met with much success (F 8).

## G. CARCINOGENESIS

All the references in this subject category were concerned with polycyclic aromatic hydrocarbons.

## H. SOIL

Addition of oil stimulates the soil microflora (H 1, 4, 6, 7, 9) and there is some evidence of selection of fungi (H 5, 10), possibly related to the lead content of the pollutants. Although significant quantities of hydrocarbons may permeate soil strata to pollute water courses (particularly groundwater), decomposition in the soil may be inhibited in the absence of adequate aeration and mineral nutrition (H 2, 8, 12, 13).

### 3. CONCLUSIONS

1. Much of the published work on pollution by petroleum hydrocarbons has been concerned with catastrophic spillages of crude and fuel oil, particularly into the sea.
2. The results of such catastrophic events are often readily measured, but there is a need for a greater understanding of the effects of chronic low-level pollution.
3. Quantitative information on the relative importance of sources of petroleum hydrocarbons in fresh water is meagre, particularly in relation to water usage. Outboard motors, sewage effluent and surface runoff should receive particular attention.
4. There are relatively few reliable estimates of microbial decomposition of petroleum products in the aquatic environment. The decomposition of mixtures of hydrocarbons (rather than individual substrates) should be studied in greater detail.
5. Observed concentration ranges of petroleum hydrocarbons in water bodies overlap those shown to exert an adverse effect on macrobiota and microorganisms. The concentration and excretion of potentially toxic substances along freshwater food chains requires further investigation.



#### 4. BIBLIOGRAPHY

##### Section A.      *Effects, Uptake, Accumulation*

- A1 Ackman, R.G. & Noble, D. (1973). Steam distillation: A simple technique for recovery of petroleum hydrocarbons from tainted fish. *J. Fish. Res. Bd Can.* 30, 711-714.
- A2 Adams, E.S. (1975). Effects of lead and hydrocarbons from snowmobile exhaust on brook trout (*Salvelinus fontinalis*). *Trans. Am. Fish. Soc.* 104, 363-373.
- A3 Anderson, J.W. (1977). Responses to sublethal levels of petroleum hydrocarbons: are they sensitive indicators and do they correlate with tissue contamination? In: *Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms* (ed. D.A. Wolfe), New York, Pergamon, 95-114.
- A4 Anderson, J.W. & Neff, J.M. (1975). Accumulation and release of petroleum hydrocarbons by edible marine animals. In: *Int. Symp., Recent advances in the assessment of the health effects of environmental pollution* 3, 1461-1469.
- A5 Atlas, R.M., Schofield, E.A. et al. (1976). Effects of petroleum pollutants on arctic microbial populations. *Envir. Pollut.* 10, 35-43.
- A6 Baker, J.M. (1970). The effects of oils on plants. *Envir. Pollut.* 1, 27-44.
- A7 Baker, J.M. (1978). Estuaries - with particular reference to hydrocarbon effects on microorganisms. In: *The oil industry and microbial ecosystems* (eds K.W.A. Chater & H.J. Somerville), London, Heyden. 51-59.
- A8 Barnett, J. & Toews, D. (1978). The effects of crude oil and the dispersant, Oilsperser 43, on respiration and coughing rates in Atlantic salmon (*Salmo salar*). *Can. J. Zool.* 56, 307-310.
- A9 Batterton, J.C. (1977). Toxicity of crude oils and fuel oils presented directly to microalgae. (Abstract only). *J. Phycol.* 13, Suppl., 6.
- A10 Baumgardner, R.K. (1966). Oxygen balance in a stream receiving domestic and oil-refinery effluent. Thesis, Okla. State Univ. 78 pp.
- A11 Bengtsson, L. & Bergren, H. (1972). The bottom fauna in an oil-contaminated lake. *Ambio*, 1, 141-144.
- A12 Berlin, J.A. & Micks, D.W. (1973). Cellular and subcellular effects of petroleum hydrocarbons on mosquito larvae. *Ann. ent. Soc. Am.* 66, 775-780.
- A13 Berry, W.O. & Brammer, J.D. (1977). Toxicity of water-soluble gasoline fractions to fourth-instar larvae of the mosquito *Aedes aegypti* L. *Envir. Pollut.* 13, 229-234.
- A14 Berry, W.O., Brammer, J.D. & Bee, D.E. (1978). Uptake of water-soluble gasoline fractions and their effects on oxygen consumption in aquatic stages of the mosquito *Aedes aegypti* (L.). *Envir. Pollut.* 15, 1-22.

- A15 Blundo, R. (1978). The toxic effects of the water soluble fractions of No. 2 fuel oil and of three aromatic hydrocarbons on the behaviour and survival of barnacle larvae. *Contr. mar. Sci. Univ Texas*, 21, 25-37.
- A16 Bott, T.L. & Rogenmuser, K. (1978). Effects of No. 2 fuel oil, Nigerian crude oil and used crankcase oil on attached algae communities: acute and chronic toxicity of water-soluble constituents. *Appl. envir. Microbiol.* 36, 673-682.
- A17 Brodersen, C.C., Rice, S.D. et al. (1977). Sensitivity of larval and adult Alaskan shrimp and crabs to acute exposures of the water soluble fraction of Cook Inlet crude oil. In: *Proc. 1977 Oil Spill Conf. (prevention, behaviour, control, cleanup)*. Washington DC, Am. Petrol. Inst. 575.
- A18 Brooks, J.M., Fryxell, G.A. et al. (1977). Gulf underwater flare experiment (GUFEX): effects of hydrocarbons on phytoplankton. In: *Pollutant effects on marine organisms* (ed C.S. Giam) Lexington, Mass. Lexington Books, 45-75.
- A19 Brown, E.R., Hazdra, J.J. et al. (1973). Frequency of fish tumors found in a polluted watershed as compared to non-polluted Canadian waters. *Cancer Res.* 33, 189-198.
- A20 Burk, C.J. (1977). A four year analysis of vegetation following an oil spill in a freshwater marsh. *J. appl. Ecol.* 14, 515-522.
- A21 Bury, R.B. (1972). The effects of diesel fuel on a stream fauna. *Calif. Fish Game*, 58, 291-295.
- A22 Calder, J.A. & Lader, J.H. (1976). Effect of dissolved aromatic hydrocarbons on the growth of marine bacteria in batch culture. *Appl. envir. Microbiol.* 32, 95-101.
- A23 Chet, I. & Mitchell, R. (1976). Petroleum hydrocarbons inhibit decomposition of organic matter in sea water. *Nature, Lond.* 261, 308-309.
- A24 Clark, R.C., Finley, T.S. & Gibson, G.G. (1974). Acute effects of outboard motor effluent on two marine shellfish. *Envir. Sci. Technol.* 8, 1009-1014.
- A25 Cooper, J.M. & Wilhm, J. (1975). Spatial and temporal variation in productivity, species diversity, and pigment diversity of periphyton in a stream receiving domestic and oil refinery effluents. *SWest. Nat.* 19, 413-427.
- A26 Copeland, B.J. & Dorris, T.C. (1964). Community metabolism in ecosystems receiving oil refinery effluents. *Limnol. Oceanogr.* 9, 431-447.
- A27 Corner, E.D.S. (1975). The fate of fossil fuel hydrocarbons in marine animals. *Proc. R. Soc. (B)*, 189, 391-413.
- A28 Corner, E.D.S., Harris, R.P. et al. (1976). Hydrocarbons in marine zooplankton and fish. In: *Effects of pollutants on aquatic organisms* (ed Lockwood A.P.M.) Cambridge, Univ. Press. 71-105.
- A29 Crocker, A.D., Cronshaw, J. & Holmes, W.N. (1974). The effects of a crude oil on intestinal absorption in duckling (*Anas platyrhynchos*). *Envir. Pollut.* 7, 165-177.

- A30 Crocker, A.D., Cronshaw, J. & Holmes, W.N. (1975). The effect of several crude oils and some petroleum distillation fractions on intestinal absorption in ducklings (*Anas platyrhynchos*). *Envir. Physiol. Biochem.* 5, 92-106.
- A31 Davavain, I.A., Mironov, O.G. & Tsimbal, I.M. (1975). Influence of oil on nucleic acids of algae. *Mar. Pollut. Bull.* 6, 13-15.
- A32 Davidson, I.E. (1972). The analysis of petroleum products in natural waters. Thesis, Chelsea Coll., Univ. Lond., 78 pp.
- A33 Dennington, V.N., George, J.J. & Wyborn, C.H.E. (1975). The effects of oils on growth of freshwater phytoplankton. *Envir. Pollut.* 8, 233-237.
- A34 Department of the Environment, Central Unit on Environmental Pollution (1976). Accidental oil pollution of the sea. *Pollut. Pap.*, 8, 170 pp.
- A35 De Vries, A.L. (1976). The physiological effect of acute and chronic exposure to hydrocarbons of petroleum on the near-shore fishes of the Bering Sea. In: *Environmental assessment of the Alaskan continental shelf*, 8. Boulder, Colorado NOAA enviro. Res. Lab., 1-14.
- A36 Dietz, A.S. Tuominen, T. & Albright, L.J. (1976). Sublethal pollutant effects upon the native microflora of Georgia Strait. In: *Proc. 3rd International biodegradation symposium, Kingston, Rhode Island*, 17-23 Aug. 1975. London, Applied Science Publ. 1083-1090.
- A37 Disalvo, L.H., Guard, H.E. et al. (1973). Hydrocarbons of suspected pollutant origin in aquatic organisms of San Francisco Bay. Methods and preliminary results. In: *The microbial degradation of oil pollutants*. (ed. D.G. Ahearn & S.P. Meyers) Proc. Wkshop Georgia State Univ., Dec. 4-6, 1972 Center Wetland Resour. Publ., LSU-SG-73-01, 205-220.
- A38 Dixit, D. & Anderson, J.W. (1977). Distribution of naphthalenes within exposed *Fundulus similis* and correlations with stress behavior. In: *Proc. 1977 Oil Spill Conf. (prevention, behaviour, control, cleanup)*. Washington DC, Am. Petrol. Inst., 633-636.
- A39 Dunstan, W.M., Atkinson, L.P. & Natoli, J. (1975). Stimulation and inhibition of phytoplankton growth by low molecular weight hydrocarbons. *Mar. Biol.* 31, 305-310.
- A40 English, J.N., McDermott, G.N. & Henderson, C. (1963). Pollutational effects of outboard motor exhaust - laboratory studies. *J. Wat. Pollut. Contrl Fed.* 35, 923-931.
- A41 English, J.N., Surber, E.W. & McDermott, G.N. (1963). Pollutational effects of outboard motor exhaust - field studies. *J. Wat. Pollut. Control Fed.* 35, 1121-1132.
- A42 Ereditario, J.M. & Pfaender, F.K. (1977). Effect of petroleum hydrocarbons on salt marsh microbial communities. (Abstract only) *Abstr. a. Meet. Am. Soc. Microbiol.* 77, 240.
- A43 Field Studies Council (1968). The biological effects of oil pollution on littoral communities. *Field Stud.* 2, Suppl., 197 pp.
- A44 Forns, J.M. (1977). The effects of crude oil on larvae of lobster *Homarus americanus*. In: *Proc. 1977 Oil Spill Conf. (prevention, behaviour, control, cleanup)* Washington DC, Am. Petrol. Inst., 569-574.



- A45 Fucik, K.W., Armstrong, H.W. & Neff, J.M. (1977). Uptake of naphthalenes by the clam, *Rangia cuneata*, in the vicinity of an oil separator platform in Trinity Bay, Texas. In: *Proc. 1977 Oil Spill Conf. (prevention, behaviour, control, cleanup)* Washington DC, Am. Petrol. Inst., p. 637.
- A46 George, J.D. (1971). The effects of pollution by oil and oil dispersants on the common inter-tidal polychaetes, *Cirriiformia tentaculata* and *Cirratulus cirratus*. *J. appl. Ecol.* 8, 411-420.
- A47 Geraci, J.R. & Smith, T.G. (1976). Behaviour and pathophysiology of seals exposed to crude oil. In: *Proc. Symp. Sources, effects and sinks of hydrocarbons in the aquatic environment*. Arlington, Va, Am. Inst. biol. Sci., 448-462.
- A48 Gordon, D.C. & Prouse, N.J. (1973). The effects of three oils on marine phytoplankton photosynthesis. *Mar. Biol.* 22, 329-333.
- A49 Hanna, B.M., Hellebust, J.A. & Hutchinson, T.C. (1975). Field studies on the phytotoxicity of crude oil to subarctic aquatic vegetation. *Verh. int. Verein. theor. angew. Limnol.* 19, 2165-2171.
- A50 Hellebust, J.A., Hanna, B. et al. (1975). Experimental crude oil spills on a small subarctic lake in the Mackenzie Valley, NWT: effects on phytoplankton, periphyton, and attached aquatic vegetation. In: *Proc. 1975 Conf. Prev. Control Oil Pollut.*, San Francisco, Calif., 25 Mar., 1975, 509-515.
- A51 Herbes, S.E. (1977). Partitioning of polycyclic aromatic hydrocarbons between dissolved and particulate phases in natural waters. *Wat. Res.* 11, 493-496.
- A52 Hodgins, H.O., Gronlund, W.D. et al. (1977). Effect of crude oil on trout reproduction. In: *Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms*. Proc. Symp. Nov. 10-12, 1976, Seattle, Wash. (ed. D.A. Wolfe). New York, Pergamon, 143-150.
- A53 Hodson, R.E., Azam, F. & Lee, R.F. (1975). Effect of four oils on coastal marine microbial populations: a controlled ecosystem pollution experiment. In: *A Rep. natn. Sci. Fdn. - Int. Decade Ocean Explor. Controlled ecosystem pollution experiment (CEPEX)*, May 1, 1974 - May 1, 1975, Sect. 12, 15 pp.
- A54 Hoehn, R.C., Stauffer, J.R. et al. (1974). Relationship between sediment oil concentrations and the macroinvertebrates present in a small stream following an oil spill. *Envir. Lett.* 7, 345-352.
- A55 Horowitz, A. & Atlas, R.M. (1977). Response of microorganisms to an accidental gasoline spillage in an arctic freshwater ecosystem. *Appl. envir. Microbiol.* 33, 1252-1258.
- A56 Hyland, J.L. & Schneider, E.D. (1976). Petroleum hydrocarbons and their effects on marine organisms, populations, communities and ecosystems. In: *Proc. Symp. Sources, effects and sinks of hydrocarbons in the aquatic environment*. Arlington, Va, Am. Inst. biol. Sci., 464-506.
- A57 Idoniboye-obu, B. (1977). Bioelectric action potentials of *Procambarus acutus acutus* (Girard) in serially diluted solutions of selected C<sub>6</sub> hydrocarbons in water. *Envir. Pollut.* 14, 5-24.



- A58 Jackivicz, T.P. & Kuzminski, L.N. (1973). The effects of the interaction of outboard motors with the aquatic environment - a review. *Envir. Res.* 6, 436-454
- A59 Jackivicz, T.P. & Kuzminski, L.N. (1973). A review of outboard motor effects on the aquatic environment. *J. Wat. Pollut. Control Fed.* 45, 1759-1770.
- A60 Jahn, W. (1972). Ecological investigations of ponds with special regard to the consequences of water pollution by oil. *Arch. Hydrobiol.* 70, 442-483. (German with English summary).
- A61 Kauss, P.B. & Hutchinson, T.C. (1975). The effects of water-soluble petroleum components on the growth of *Chlorella vulgaris* Beijerinck. *Envir. Pollut.* 9, 157-174.
- A62 Kauss, P.B. & Hutchinson, T.C. (1975). Studies on the susceptibility of *Ankistrodesmus* spp. to crude oil components. *Verh.int. Verein. theor. angew. Limnol.* 19, 2155-2164.
- A63 Kauss, P., Hutchinson, T.C. et al. (1973). The toxicity of crude oil and its components to freshwater algae. In: *Prevention and control of oil spills*. Proc. Joint. Conf., 13-15 Mar., 1973, Washington DC, 703-714.
- A64 Kempf, T., Ludemann, D. & Pflaum, W. (1967). Pollution of waters by motorized operations, especially by outboard motors. *SchrReihe Ver. Wass.-Boden- u. Lufthyg.*, 26, 48 pp.
- A65 Koroleva, A.M. (1977). Changes in zooplankton numbers under the effect of petroleum pollutants and dispersants. *Vest. mosk. Univ., Ser. XVI Biol.*, 1, 30-33. (Russian with English summary)
- A66 Kravchenko, M.E. & Gapochka, L.D. (1977). The effect of oil and oil products on some blue-green algae. *Izv. Akad. Nauk turkmen. SSR, Ser. biol. Nauk*, 2, 52-56.
- A67 Krishnaswami, S.K. & Kupchanko, E.E. (1969). Relationship between odor of petroleum refinery waste-water and occurrence of "oily" taste-flavor in rainbow trout, *Salmo gairdnerii*. *J. Wat. Pollut. Contr. Fed.* 41, 5 part 2, R189-R196.
- A68 Kuhnhold, W.W. (1972). The influence of crude oils on fish fry. In: *Marine pollution and sea life* (ed.M. Ruivo). Surrey, Fishing News (Books), 315-318.
- A69 Kumar, I.J. (1972). Effect of outboard engine exhaust on phytoplankton. A preliminary report. *Rensselaer Freshwat. Inst. Newsl.* 2, 4, 1-2.
- A70 Kusk, K.O. (1978). Effects of crude oil and aromatic hydrocarbons on the photosynthesis of the diatom *Nitzschia palea*. *Physiologia Pl.* 43, 1-6.
- A71 Larson, R.A., Hunt, L.L. & Blakenship, D.W. (1977). Formation of toxic products from a No. 2 fuel oil by photo-oxidation. *Envir. Sci. Technol.* 11, 492-496.
- A72 Lawler, G.C., Loong, W-A. & Laseter, J.L. (1978). Accumulation of saturated hydrocarbons in tissues of petroleum-exposed mallard ducks (*Anas platyrhynchos*). *Envir. Sci. Technol.* 12, 47-51.
- A73 Lawler, G.C., Loong, W-A. & Laseter, J.L. (1978). Accumulation of aromatic hydrocarbons in tissues of petroleum-exposed mallard ducks (*Anas platyrhynchos*). *Envir. Sci. Technol.* 12, 51-54.

- A74 Lee, R.F. (1977). Accumulation and turnover of petroleum hydrocarbons in marine organisms. In: *Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms*. Proc. Symp., Nov. 10-12, 1976, New York, Pergamon, 60-70.
- A75 Lockwood, A.P.M. (ed.) (1976). *Effects of pollutants on aquatic organisms*. Proc. Semin., Liverpool Univ., Apr. 1975, 193 pp.
- A76 Logan, J.W.M. & Perkins, E.J. (1972). Toxicity of Essolve. *Mar. Pollut. Bull.* 3, 155-157.
- A77 Mackie, P.R., McGill, A.S. & Hardy, R. (1972). Diesel oil contamination of brown trout (*Salmo trutta* L.). *Envir. Pollut.* 3, 9-16.
- A78 Maksimov, V.N. (1977). Analysis of combined effect of pollutants on biological systems. *Hydrobiol. J.* 13, 4, 28-37.
- A79 Malins, D.C., Hodgens, H.O. & Weber, D.D. (1976). Sublethal effects as reflected by morphological, chemical, physiological and behavioural indices. In: *Environmental assessment of Alaskan continental shelf*, 8. Boulder, Colorado, NOAA envir. Res. Lab., 119-
- A80 Marshall, H.G. (1975). Phytoplankton studies in the coastal waters between Cape Hatteras and the Gulf of Maine; with comments on the interaction of natural phytoplankton populations and oil pollution. In: *Marine environmental implications of offshore and gas development in the Baltimore Canyon region of the mid-Atlantic coast*. Proc. estuar. Res. Fedn Outer Continental Shelf Conf. Wkshop, Dec. 2-4, 1974. Wachapreague, Va, Estuar. Res. Fdn, 265-276.
- A81 Masnik, M.T., Stauffer, J.R. et al. (1976). The effects of an oil spill on the macroinvertebrates and fish in a small southwestern Virginia creek. *J. envir. Sci. Hlth*, 11, 281-291.
- A82 Mazmanidi, N.D. & Bazhashivilli, T.R. (1975). Effects of dissolved petroleum products on the embryonic development of the Black Sea flounder. *Hydrobiol. J.* 11, 5, 39-43.
- A83 Mazmanidi, N.D. & Kovaleva, G.I. (1975). The effect of dissolved petroleum products on some of the aspects of carbohydrate metabolism in fishes and invertebrates. *J. Ichthyol.* 15, 811-816.
- A84 McCauley, R.N. (1964). The biological effects of oil pollution in a river. Thesis, Cornell Univ., 185 pp.
- A85 McCauley, R.N. (1966). The biological effects of oil pollution in a river. *Limnol. Oceanogr.* 11, 475-486.
- A86 McKeown, B.A. & March, G.L. (1978). The acute effect of Bunker C oil and an oil dispersant on serum glucose, serum sodium and gill morphology in both freshwater and sea water acclimated rainbow trout (*Salmo gairdneri*). *Wat. Res.* 12, 157-163.
- A87 Meyerhoff, R.D. (1975). Acute toxicity of benzene, a component of crude oil to juvenile striped bass (*Morone saxatilis*). *J. Fish. Res. Bd Can.* 32, 1864-1866.
- A88 Mironov, O.G. (1969). Development of some Black Sea fish in sea water polluted by petroleum products. *J. Ichthyol.* 9, 919-922.
- A89 Mironov, O.G. (1972). Effect of oil pollution on flora and fauna of the Black Sea. In: *Marine pollution and sea life* (ed. M. Ruivo). Surrey, Fishing News (Books), 222-224.

- A90 Mitchell, R. (1974). *The effects of pollution on marine microbial processes: a field study*. Cambridge, Mass., Harvard Univ. Div. Engng. appl. Phys., 42 pp.
- A91 Moore, S.F. & Dwyer, R.L. (1974). Effect of oil on marine organisms - a critical assessment of published data. *Wat. Res.* 8, 819-827.
- A92 Morrow, J.E. (1973). Oil induced mortalities in juvenile coho and sockeye salmon. *J. mar. Res.* 31, 135-43
- A93 Morrow, J.E. (1974). Effects of crude oil and some of its components on young coho and sockeye salmon. *U.S. envir. Prot. Ag., ecol. Res. Ser.*, EPA-660/3-73-018.
- A94 Morrow, J.E., Gritz, R.L. & Kirton, M.P. (1975). Effects of some components of crude oil on young coho salmon. *Copeia* 2, 326-331.
- A95 Muller, D. & Hellmann, H. (1976). On the toxic effects of mineral oils and internal combustion engine fuels on the self-purification processes in natural waters. *Gas- u. WassFach* 117, 369-373.
- A96 Nadeau, R.J. & Roush, T.H. (1972). Biological effects of oil pollution. Selected bibliography. *U.S. envir. Prot. Ag. Office Res. Monit.*, EPA-R2-72-055.
- A97 Nauman, J.W. & Kernodle, D.R. (1975). The effect of fuel oil spill on benthic invertebrates and water quality on the Alaskan arctic slope, Happy Valley Creek, near Sagwon, Alaska. *J. Res. U.S. geol. Surv.* 3, 495-500.
- A98 Neff, J.M. (1975). Accumulation and release of petroleum-derived aromatic hydrocarbons by marine animals. *Am. Chem. Soc. Petrol. Chem. Div. Preprints*, 20, 839-850.
- A99 Neff, J.M., Anderson, J.W. et al. (1976). Effects of petroleum on survival, respiration and growth of marine animals. In: *Proc. Symp. Sources effects and sinks of hydrocarbons in the aquatic environment*. Arlington, Va, Am. Inst. biol. Sci., 516-539.
- Al00 Neff, J.M., Cox, B.A. et al. (1976). Accumulation and release of petroleum-derived aromatic hydrocarbons by four species of marine animals. *Mar. Biol.* 38, 279-289.
- Al01 Nelson-Smith, A. (1968). A classified bibliography of oil pollution. In: *The biological effects of oil pollution on littoral communities*. Suppl. to Vol. 2. Field Stud. Coun., 165-196.
- Al02 Norrell, S.A. & Johnston, M.H. (1976). Effects of oil on microbial component of an intertidal silt-sediment ecosystem. In: *Assessment of the arctic marine environment: Selected topics* (eds D.W. Hood and D.C. Burrell,, Fairbanks, Alaska, Institute of Marine Science, 305-327.
- Al03 Nuzzi, R. (1973). Effects of water soluble extracts of oil on phytoplankton. In: *Prevention and control of oil spills*. Proc. joint Conf., 13-15 Mar., 1973, Washington DC, 809-813.
- Al04 O'Brien, P.Y. & Dixon, P.S. (1976). The effects of oils and oil components on algae: a review. *Br. phycol. J.* 11, 115-142.
- Al05 Ogata, M. & Miyake, Y. (1973). Identification of substances in petroleum causing objectionable odour in fish. *Wat. Res.* 7, 1493-1504.



- A106 Ogata, M., Miyake, Y. et al. (1977). Transfer to fish of petroleum paraffins and organic sulfur compounds. *Wat. Res.* 11, 333-338.
- A107 Ogata, M. & Ogura, T. (1976). Petroleum components and objectionable malodorous substances in fish flesh polluted by boiler fuel oil. *Wat. Res.* 10, 407-412.
- A108 Parker, B. & Barsom, G. (1970). Biological and chemical significance of surface microlayers in aquatic ecosystems. *Bioscience* 20, 87-93.
- A109 Parker, B.L. & Brammer, J.D. (1975). Effects of chronic oil contamination on aquatic dipterans. A state of the art report. U.S. Dept. Interior Report., USDI 14-31-0001-4046 (PB-237 499/9GA).
- A110 Parker, B.L., Brammer, J.D., et al. (1976). Chronic oil contamination and aquatic organisms with emphasis on Diptera; status and bibliography. *Wat. Resour. Bull.* 12, 291-305.
- A111 Parker, P.L., Winters, K. et al. (1976). Petroleum pollution: chemical characteristics and biological effects. In: *Proc. Symp. Sources, effects and sinks of hydrocarbons in the aquatic environment*. Arlington, Va, Am. Inst. biol. Sci., 257-269.
- A112 Parsons, T.R. & Li, W.K.W. (1974). Effect of very low levels of hydrocarbons on the growth of marine organisms. In: *A. Rep. natn. Sci. Fed.- Int. Decade Ocean Explor. Controlled ecosystem pollution experiment (CEPEX)*, May 1, 1974-May 1, 1975, Sect. 6, 9 pp.
- A113 Payne, J.F., Martins, I. & Rahimtula, A. (1978). Crankcase oils: are they a major mutagenic burden in the aquatic environment? *Science*, N.Y. 200, 329-330.
- A114 Pessah, E., Loch, J.S. & Macleod, J.C. (1973). Preliminary report on the acute toxicity of Canadian petroleum refinery effluents to fish. *Tech. Rep. Fish. Res. Bd Can.*, 408, 43 pp.
- A115 Pickering, Q.H. & Henderson, C. (1966). Acute toxicity of some important petrochemicals to fish. *J. Wat. Pollut. Control Fed.* 38, 1419-1429.
- A116 Rice, S.D. (1973). Toxicity and avoidance tests with Prudhoe Bay oil and pink salmon fry. In: *Proc. Joint Conf. Prevention and control of oil spills*, Washington DC, 667-670.
- A117 Rice, S.D., Short, J.W. & Karinen, J.F. (1977). Comparable oil toxicity and comparative animal sensitivity. In: *Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms*. *Proc. Symp.*, Nov. 10-12, 1976, New York, Pergamon, 78-94.
- A118 Rosenberg, D.M. & Wiens, A.P. (1976). Community and species responses of Chironomidae (Diptera) to contamination of fresh waters by crude oil and petroleum products with special reference to the Trail River, Northwest Territories. *J. Fish. Res. Bd Can.* 33, 1955-1963.
- A119 Rosenberg, D.M., Wiens, A.P. & Saether, O.A. (1977). Responses to crude oil contamination by *Cricotopus* (*Cricotopus*) *bicinctus* and *C. (C.) mackenziensis* (Diptera: Chironomidae) in the Fort Simpson area, Northwest Territories. *J. Fish. Res. Bd Can.* 34, 254-261.



- A120 Rossi, S.S. & Anderson, J.W. (1976). Toxicity of water-soluble fractions of No. 2 fuel oil and south Louisiana crude oil to selected stages in the life history of the polychaete, *Neanthes arenaceodentata*. *Bull. envir. Contam. Toxic.* 16, 18-24.
- A121 Rossi, S.S., Anderson, J.W. & Ward, G.S. (1976). Toxicity of water-soluble fractions of four test oils for the polychaetous annelids, *Neanthes arenaceodentata* and *Capitella capitata*. *Envir. Pollut.* 10, 9-18.
- A122 Russell, F. & Gilson, H.C. (1972). A discussion on freshwater and estuarine studies of the effects of industry. *Proc. R. Soc. (B)* 180, 363-541.
- A123 Sacherer, F.A. & Krassnigg, F. (1970). The effect on organisms of prolonged contact with oil polluted water. *Z. Wass. Abwass. Forsch.* 3, 99-101.
- A124 Shindler, D.B., Scott, B.F. & Carlisle, D.B. (1975). Effect of crude oil on populations of bacteria and algae in artificial ponds subject to winter weather and ice formation. *Verh. int. Verein. theor. angew. Limnol.* 19, 2138-2144.
- A125 Shuster, W.S. (1974). Effects of exhaust from 2-cycle outboard engines. *U.S. envir. Prot. Ag., envir. Prot. Tech. Rep.*, EPA-670/2-74-063.
- A126 Snow, N.B. & Rosenberg, D.M. (1975). Experimental oil spills on Mackenzie Delta lakes 1. Effects of Norman Wells crude oil on lake 4. *Tech. Rep. Can. Fish. mar. Serv.*, 548, 53 pp.
- A127 Snow, N.B. & Scott, B.F. (1975). The effect and fate of crude oil spilt on two arctic lakes. In: *Proc. 1975 Conf. Prev. Control Oil Pollut.*, San Francisco, Calif., 25 Mar. 1975, 527-534.
- A128 Soto, C., Hellebust, J.A. et al. (1975). Effect of naphthalene and aqueous crude oil extracts on the green flagellate *Chlamydomonas angulosa*: I. Growth. *Can. J. Bot.* 53, 109-117.
- A129 Soto, C., Hellebust, J.A. & Hutchinson, T.C. (1975). Effect of naphthalene and aqueous crude oil extracts on the green flagellate *Chlamydomonas angulosa*: II. Photosynthesis and the uptake and release of naphthalene. *Can. J. Bot.* 53, 118-126.
- A130 Soto, C., Hellebust, J.A. & Hutchinson, T.C. (1975). The effects of aqueous extracts of crude oil and naphthalene on the physiology and morphology of a freshwater green alga. *Verh. int. Verein. theor. angew. Limnol.* 19, 2145-2154.
- A131 Soto, C., Hellebust, J.A. & Hutchinson, T.C. (1977). Effect of naphthalene and aqueous crude oil extracts on the green flagellate *Chlamydomonas angulosa*. III. Changes in cellular composition. *Can. J. Bot.* 55, 2765-2777.
- A132 Steele, R.L. (1977). Sensitivity of some brown algal reproductive stages to oil pollution. (Abstract only). *J. Phycol.* 13, Suppl., 64.
- A133 Stegeman, J.J. & Sabo, D.J. (1975). Uptake and release of petroleum hydrocarbons by marine organisms and some metabolic implications. In: *Marine environmental implications of offshore and gas development in the Baltimore Canyon region of the mid-Atlantic coast*. Proc. estuar. Res. Fedn Outer Continental Shelf Conf. Wkshop, Dec. 2-4, 1974. Wachapreague, Va. Estuar. Res. Fedn, 339-350.

- A134 Straughan, D. (1977). The sub-lethal effects of natural chronic exposure to petroleum on marine invertebrates. In: *Proc. 1977 Oil Spill Conf. (prevention, behaviour, control, cleanup)* Washington DC, Am. Petrol. Inst., 563-568.
- A135 Swain, H.M., Somerville, H.J. & Cole, J.A. (1978). Denitrification during growth of *Pseudomonas aeruginosa* in octane. *J. gen. Microbiol.* 107, 103-112.
- A136 Takahashi, F.T. & Kittredge, J.S. (1973). Sublethal effects of the water soluble component of oil: chemical communication in the marine environment. In: *The microbial degradation of oil pollutants*. Proc. Wkshop Georgia State Univ., Dec. 4-6 (eds D.G. Ahearn, S.P. Meyers). Center Wetland Resour. Publ., LSU-SG-73-01, 259-264.
- A137 Tatem, H.E., Cox, B.A. & Anderson, J.W. (1978). The toxicity of oils and petroleum hydrocarbons to estuarine crustaceans. *Estuar. coastal mar. Sci.* 6, 365-373.
- A138 Teal, J.M. (1976). Hydrocarbon uptake by deep sea benthos. In: *Proc. Symp. Sources, effects and sinks of hydrocarbons in the aquatic environment*. Arlington, Va, Am. Inst. biol. Sci., 359-371.
- A139 Thomas, R.E. & Rice, S.D. (1975). Increased opercular rates of pink salmon (*Oncorhynchus gorbuscha*) fry after exposure to the water soluble fraction of Prudhoe Bay crude oil. *J. Fish. Res. Bd Can.* 32, 2221-2224.
- A140 Thompson, S. & Eglington, G. (1976). The presence of pollutant hydrocarbons in estuarine epipellic diatom populations. *Estuar. coastal mar. Sci.* 4, 417-425.
- A141 Vandermeulen, J.H. & Ahern, T.P. (1976). Effect of petroleum hydrocarbons on algal physiology: review and progress report. In: *Effects of pollutants on aquatic organisms* (ed. A.P.M. Lockwood) Cambridge, Univ. Press, 107-125.
- A142 Van der Waarden, M., Groenewoud, W.M. & Bridie, A.L.A.M. (1977). Transport of mineral oil components to groundwater: II. Influence of lime, clay and organic soil components on the rate of transport. *Wat. Res.* 11, 359-366.
- A143 Vestal, J.R., Federle, T.W. et al. (1977). The effect of Prudhoe crude oil on primary production in Arctic ponds. (Abstract only) *Abstr. a. Meet. Am. Soc. Microbiol.* 77, 268.
- A144 Walker, J.D. & Colwell, R.R. (1975). Some effects of petroleum on estuarine and marine microorganisms. *Can. J. Microbiol.* 21, 305-313.
- A145 Walker, J.D. & Pore, R.S. (1978). Growth of *Prototheca* isolates on n-hexadecane and mixed hydrocarbon substrate. *Appl. envir. Microbiol.* 35, 694-697.
- A146 Walker, J.D., Seesman, P.A. & Colwell, R.R. (1975). Effect of S. Louisiana crude oil and No. 2 fuel oil on growth of heterotrophic microorganisms, including proteolytic, lipolytic, chitinolytic and cellulolytic bacteria. *Envir. Pollut.* 9, 13-33.

- A147 Walsh, F. & Mitchel, R. (1973). Inhibition of bacterial chemoreception by hydrocarbons. In: *The microbial degradation of oil pollutants*. Proc. Wkshop Georgia State Univ., Dec. 4-6, 1972 (eds D.G. Ahearn, S.P. Meyers). Center Wetland Resour. Publ., LSU-SG-73-01, 275-278.
- A148 Wilhm, J.L. (1965). Species diversity of benthic macro-invertebrates in a stream receiving domestic and oil refinery effluents. Thesis Oklahoma State Univ., 49 pp.
- A149 Wilhm, J.L. & Dorris, T.C. (1966). Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluents. *Am. Midl. Nat.* 76, 427-449.
- A150 Wilson, K.W. (1974). Toxicity testing for ranking oils and oil dispersants In: *Ecological aspects of toxicity testing of oils and dispersants*. Proc. Wkshop, London, England (eds L.R. Beynon & E.B. Cowell), New York, Halstead, 11-22.
- A151 Winters, K., Batterton, J.C. et al. (1977). Fuel oils. Chemical characterization and toxicity to microalgae. In: *Pollutant effects on marine organisms* (ed. C.S. Giam) Lexington, Mass, Lexington Books, 167-189.
- A152 Winters, K., Batterton, J.C. & Van Baalen, C. (1977). Phenalen-1-one: occurrence in a fuel oil and toxicity to microalgae. *Envir. Sci. Technol.* 11, 270-272.
- A153 Winters, K., O'Donnell, R. et al. (1976). Water-soluble components of four fuel oils: chemical characterization and effects on growth of microalgae. *Mar. Biol.* 36, 269-276.
- A154 Zimmerman, W. (1970). The effect of mineral oil on ground water. *Gewassersch. Wass. Abwass.* 3, 23-41.
- A155 Zsolnay, A., Maynard, N.G. & Gebelein, C.D. (1977). Biogenic hydrocarbons in intertidal communities. In: *Proc. 1977 Oil Spill Conf. (prevention, behaviour, control, cleanup)* Washington, DC, Am. Petrol. Inst., 173-178.



Section B.      *Microbial Utilization, Degradation*

- B1    Ahearn, D.G. & Meyers, S.P. (1976). Fungal degradation of oil in the marine environment. In: *Recent advances in aquatic mycology* (ed. E.B.G. Jones) London, Paul Elek. 125-133.
- B2    Atlas, R.M. (1975). Effects of temperature and crude oil composition on petroleum biodegradation. *Appl. Microbiol.* 30, 396-403.
- B3    Atlas, R.M. (1977). Studies on petroleum biodegradation in the Arctic. In: *Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms* (ed. D.A. Wolfe), New York, Pergamon, 261-269.
- B4    Atlas, R.M. & Schofield, E.A. (1975). Petroleum biodegradation in the Arctic. In: *Impact of the use of microorganisms on the aquatic environment* (eds A.W. Burquin, D.G. Ahearn & S.P. Meyers) U.S. envir. Prot. Ag., envir. Prot. Technol. Ser., EPA-660-3-75-001, 183-189.
- B5    Baier, R.E. (1972). Organic films on natural water: their retrieval, identification, and modes of elimination. *J. geophys. Res.* 77, 5062-5075.
- B6    Bartha, R. & Atlas, R.M. (1973). Biodegradation of oil in seawater: limiting factors, and artificial stimulation. In: *The microbial degradation of oil pollutants*. Proc. Wkshop Georgia State Univ., Dec. 4-6, 1972 (eds D.G. Ahearn, S.P. Meyers) Center Wetland Resour. Publ., LSU-SG-73-01, 147-152.
- B7    Beam, H.W. & Perry, J.J. (1974). Microbial degradation of cycloparaffinic hydrocarbons via co-metabolism and commensalism. *J. gen. Microbiol.* 82, 163-169.
- B8    Bohonos, N., Chout, W. & Spanggord, R.J. (1977). Some observations on biodegradation of pollutants in aquatic systems. *Jap. J. Antibiot.* 30, Suppl., 275-285.
- B9    Breuil, C. & Shindler, D.B. (1977). Effects of crude oil on bacterial and fungal populations in freshwater artificial ponds. (Abstract only). *Abstr. a. Meet. Am. Soc. Microbiol.* 77, 269.
- B10   Brown, L.R. & Tischer, R.G. (1969). The decomposition of petroleum products in our natural waters. *Rep. Wat. Resour. Res. Inst.*, A-027-Miss, 40 pp.
- B11   Bunch, J.N. & Harland, R.C. (1976). Biodegradation of crude petroleum by the indigenous microbial flora of the Beaufort Sea. *Beaufort Sea Tech. Rep.* 10, 52 pp.
- B12   Button, D.K. (1974). Arctic oil biodegradation. Final report. U.S. Coast Guard, Dept. Transportation DOT-CG-114-75, 37 pp.
- B13   Chater, K.W.A. & Somerville, H.J. (eds) (1978). The oil industry and microbial ecosystems. London, Heyden.
- B14   Colwell, R.R., Walker, J.D. & Nelson, J.D. (1973). Microbial ecology and the problems of petroleum degradation in Chesapeake Bay. In: *The microbial degradation of oil pollutants*. Proc. Wkshop Georgia State Univ., Dec. 4-6, 1972 (eds D.G. Ahearn, S.P. Meyers) Center Wetland Resour. Publ., LSU-SG-73-01, 185-197.



- B15 Conrad, B.F., Walker, J.D. & Colwell, R.R. (1976). Utilization of crude oil and mixed hydrocarbon substrate by Atlantic Ocean microorganisms. *Devs ind. Microbiol.* 17, 282-291.
- B16 Crow, S.A., Meyers, S.P. & Ahearn, D.G. (1974). Microbiological aspects of petroleum degradation in the aquatic environment. *Mer, Tokyo*, 12, 95-112.
- B17 Davies, J.S. & Westlake, D.W.S. (1979). Crude oil utilization by fungi. *Can. J. Microbiol.* 25, 146-156.
- B18 Dean-Raymond, D. & Bartha, R. (1974). Biodegradation of some polynuclear aromatic petroleum components by marine bacteria. *Devs ind. Microbiol.* 16, 97-110.
- B19 Dietz, D.N. (1978). Large-scale experiments on ground-water pollution by oil spills: interim results. *H<sub>2</sub>O*, 11, 4, 77-80.
- B20 Fasoli, U. & Numann, W. (1973). A proposal for the application of Monod's mathematical model to the biodegradation of mineral oil in natural waters. *Wat. Res.* 7, 409-418.
- B21 Finnerty, W.R., Kennedy, R.S. et al. (1973). Microbes and petroleum: perspectives and implications. In: *The microbial degradation of oil pollutants*. Proc. Wkshop Georgia State Univ., Dec 4-6, 1972 (eds D.G. Ahearn, S.P. Meyers) Center Wetland Resour. Publ., LSU-SG-73-01, 105-125.
- B22 Floodgate, G.D. (1972). Biodegradation of hydrocarbons in the sea. In: *Water pollution microbiology* (ed. R. Mitchell). London, Wiley-Interscience, 153-171.
- B23 Gibbs, C.F. (1976). A continuously recording polarographic respirometer and its use in oil biodegradation studies. *Wat. Res.* 10, 443-451.
- B24 Gibbs, C.F. (1976). Methods and interpretation in measurement of oil biodegradation rate. In: *Proc. 3rd International Biodegradation Symposium*, 1975 (eds J.M. Sharpley & A.M. Kaplan). London, Applied Science. 127-140.
- B25 Gibson, D.T. (1977). Biodegradation of aromatic petroleum hydrocarbons. In: *Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms* (ed. D.A. Wolfe). New York, Pergamon. 36-46.
- B26 Gilewicz, M., Zacek, M. et al. (1979). Hydroxylase regulation in *Candida tropicalis* grown on alkanes. *Can. J. Microbiol.* 25, 201-206.
- B27 Groenewegen, D. & Stolp, H. (1976). Microbial breakdown of polycyclic aromatic hydrocarbons. *Zentbl. Bakt. ParasitKde, Abt. Orig. Reihe B.* 162, 225-232.
- B28 Hansen, W.G., Bitton, G. et al. (1977). Hydrocarbon status in Florida real estate canals. *Mar. Pollut. Bull.* 8, 57-62.
- B29 Herbes, S.E. & Schwall, L.R. (1978). Microbial transformation of polycyclic aromatic hydrocarbons in pristine and petroleum-contaminated sediments. *Appl. envir. Microbiol.* 35, 306-316.
- B30 Herbes, S.E., Schwall, L.R. & Williams, G.A. (1977). Rate of microbial transformation of polycyclic aromatic hydrocarbons: a chromatographic quantification procedure. *Appl. envir. Microbiol.* 34, 244-246.

- B31 Higgins, I.J. & Gilbert, P.D. (1978). The biodegradation of hydrocarbons. In: *The oil industry and microbial ecosystems* (eds K.W. A. Chater & H.J. Somerville). London, Heyden. 80-117.
- B32 Hood, M.A., Bishop, W.S. et al. (1975). Microbial indicators of oil-rich salt-marsh sediments. *Appl. Microbiol.* 30, 982-987.
- B33 Horowitz, A. & Atlas, R.M. (1977). Interactions of microorganisms and hydrocarbons following an accidental leakage of gasoline into a freshwater lake at Barrow, Alaska. (Abstract only). *Abstr. a. Meet. Am. Soc. Microbiol.* 77, 275.
- B34 Hughes, D.E. & McKenzie, P. (1975). The microbial degradation of oil in the sea. *Proc. R. Soc. (B)*, 189, 375-390.
- B35 Hughes, D.E. & Stafford, S. (1976). Bacterial degradation of crude oil. In: *The control of oil pollution on the sea and inland waters* (ed. J.W. Smith). London, Graham & Trotman. 39-46.
- B36 Jobson, A., Cook, F.D. & Westlake, D.W.S. (1972). Microbial utilization of crude oil. *Appl. Microbiol.* 23, 1082-1089.
- B37 Johnston, R. (1970). The decomposition of crude oil residues in sand columns. *J. mar. biol. Ass. U.K.* 50, 925-937.
- B38 Kaplin, V. & Kolesnikova, T. (1971). Dispersion of pollutants and processes of self-purification in lakes and reservoirs. *Verh. int. Verein. theor. angew. Limnol.* 18, 942-945.
- B39 Kappeler, T. & Wuhrmann, K. (1978). Microbial degradation of the water-soluble fraction of gas oil. I. *Wat. Res.* 12, 327-333.
- B40 Kappeler, T. & Wuhrmann, K. (1978). Microbial degradation of the water-soluble fraction of gas oil. II. Bio-assays with pure strains. *Wat. Res.* 12, 335-342.
- B41 Kator, H., Oppenheimer, C.H. & Miget, R.J. (1971). Microbial degradation of oil pollutants. *Biol. Conserv.* 4, 12.
- B42 Larock, P.A. & Ahlfeld, T.E. (1973). The relative changes in n-alkane composition in surface water slicks. In: *The microbial degradation of oil pollutants*. Proc. Wkshop Georgia State Univ., Dec. 4-6, 1972 (eds D.G. Ahearn, S.P. Meyers). Center Wetland Resour. Publ., LSU-SG-73-01, 233-236.
- B43 Lee, R.T. (1976). Metabolism of petroleum hydrocarbons in marine sediments. In: *Proc. Symp. Sources, effects and sinks of hydrocarbons in the aquatic environment*. Arlington, Va, Am. Inst. biol. Sci. 334-344.
- B44 Liu, D.L.S. (1973). Microbial degradation of crude oil and the various hydrocarbon derivatives. In: *The microbial degradation of oil pollutants*. Proc. Wkshop Georgia State Univ., Dec. 4-6, 1972 (eds D.G. Ahearn, S.P. Meyers). Center Wetland Resour. Publ., LSU-SG-73-01, 95-104.
- B45 Liu, D.L. & Dutka, B.J. (1973). Biological oxidation of hydrocarbons in aqueous phase. *J. Wat. Pollut. Control Fed.* 45, 232-239.
- B46 McAuliffe, C.D. (1977). Dispersal and alteration of oil discharged on a water surface. In: *Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms*. (ed. D.A. Wolfe). New York, Pergamon. 19-35.

- B47 McKee, J.E., Laverty, F.B. & Hertel, R.M. (1972). Gasoline in ground water. *J. Wat. Pollut. Control Fed.* 44, 293-302.
- B48 McKenna, E.J. & Heath, R.D. (1976). Biodegradation of polynuclear aromatic hydrocarbon pollutants by soil and water microorganisms. *Res. Rep. Univ. Ill. Urbana-Champaign Wat. Resour. Center*, 113, 1-25.
- B49 McKenzie, P. & Hughes, D.E. (1976). Microbial degradation of oil and petrochemicals in the sea. In: *Microbiology in agriculture, fisheries and food* (eds F.A. Skinner & J.G. Carr). London, Academic. 91-108.
- B50 Mechalas, B.J., Meyers, T.J. & Kolpack, R.L. (1973). Microbial decomposition patterns using crude oil. In: *The microbial degradation of oil pollutants*. Proc. Wkshop Georgia State Univ., Dec. 4-6, 1972 (eds D.G. Ahearn, S.P. Meyers). Center Wetland Resour. Publ., LSU-SG-73-01, 67-79.
- B51 Morozov, N.V., Petrova, R.B. & Petrov, G.N. (1969). The role of the higher water vegetation in self-purification of waters from oil impurity. *Gidrobiol Zh., Kiev*, 5, 4, 73-79 (Russian with English summary).
- B52 Morozov, N.V. & Torpishcheva, A.V. (1973). Microorganisms oxidizing petroleum and petroleum products in the presence of higher aquatic plants. *Hydrobiol. J.* 9, 4, 54-59.
- B53 Mulkins-Phillips, G.J. & Stewart, J.E. (1974). Effect of environmental parameters on bacterial degradation of Bunker C oil, crude oils and hydrocarbons. *Appl. Microbiol.* 28, 915-922.
- B54 Parekh, V.R., Traxler, R.W. & Sobek, J.M. (1977). *n*-Alkane oxidation enzymes of a pseudomonad. *Appl. envir. Microbiol.* 33, 881-884.
- B55 Perry, J.J. & Cerniglia, C.E. (1973). Studies on the degradation of petroleum by filamentous fungi. In: *The microbial degradation of oil pollutants*. Proc. Wkshop Georgia State Univ., Dec. 4-6, 1972 (eds D.G. Ahearn, S.P. Meyers). Center Wetland Resour. Publ., LSU-SG-73-01, 89-94.
- B56 Petrov, G.N. (1969). Removal of petroleum from water reservoirs by the action of higher aquatic vegetation and micro-organisms. *Neftepromysl. Delo*, 9, 27-30.
- B57 Pierce, R.H., Cundell, A.M. & Traxler, R.W. (1975). Persistence and biodegradation of spilled residual fuel oil on an estuarine beach. *Appl. Microbiol.* 29, 646-652.
- B58 Pritchard, P.H. & Starr, T.J. (1975). The microbial degradation of oil in continuous culture. *Natn. tech. Inf. Serv. Publ.*, AD/A-013 322, 86 pp.
- B59 Pritchard, P.H. & Ventullo, R.M. (1975). The response of bacterial populations to organic pollutants in Lake Ontario. The development of a laboratory model involving oil degradation. *Proc. Rochester Acad. Sci.* 12, 402-404.
- B60 Robertson, B., Arhelger, S. et al. (1973). Hydrocarbon biodegradation in Alaskan waters. In: *The microbial degradation of oil pollutants*. Proc. Wkshop Georgia State Univ., Dec. 4-6, 1972 (eds D.G. Ahearn & S.P. Meyers). Center Wetland Resour. Publ., LSU-SG-73-01, 171-184.



- B61 Seesman, P.A., Walker, J.D. & Colwell, R.R. (1976). Biodegradation of oil by marine microorganisms at potential off-shore drilling sites. In: *Developments in industrial microbiology*. Proc. 32nd gen. Meet. Soc. ind. Microbiol., Kingston, Rhode Island, 17-22 Aug, 1975, vol. 17. Washington, DC, Am. Inst. biol. Sci. 293-299.
- B62 Seki, H. (1976). Method for estimating the decomposition of hexadecane in the marine environment. *Appl. envir. Microbiol.* 31, 439-441
- B63 Shaposhnikov, V.N., Kozlova, E.I. & Arkad'eva, Z.A. (1968). Study of microflora of oil-containing sewage. *Mikrobiologiya*, 37, 511-517 (Russian with English summary).
- B64 Shelton, T.B. & Hunter, J.V. (1974). Aerobic decomposition of oil pollutants in sediments. *J. Wat. Pollut. Control Fed.* 46, 2172-2182.
- B65 Shelton, T.B. & Hunter, J.V. (1975). Anaerobic decomposition of oil in bottom sediments. *J. Wat. Pollut. Control Fed.* 47, 2256-2270.
- B66 Stanev, Ts. (1977). Anaerobic oxidation of hydrocarbons by *Desulfovibrio desulfuricans*. *Izv. Inst. rybn. Resur. Varna*, 5, 115-120. (Bulgarian with English summary).
- B67 Stanley, S.O., Pearson, T.H. & Brown, C.M. (1978). Marine microbial ecosystems and the degradation of organic pollutants. In: *The oil industry and microbial ecosystems* (eds K.W.A. Chater & H.J. Somerville). London, Heyden. 60-79.
- B68 Traxler, R.W. & Bernard, J.M. (1969). The utilization of n-alkanes by *Pseudomonas aeruginosa* under conditions of anaerobiosis. I. Preliminary observation. *Int. Biodetn Bull.* 5, 21-25.
- B69 Vater, W. (1967). The effect of mineral oil on the digestion of sewage sludge. *Gas-u. WassFach*, 108, 51-52.
- B70 Walker, J.D. & Colwell, R.R. (1974). Microbial petroleum degradation: use of mixed hydrocarbon substrates. *Appl. Microbiol.* 27, 1053-1060.
- B71 Walker, J.D. & Colwell, R.R. (1974). Microbial degradation of model petroleum at low temperatures. *Microbial Ecol.* 1, 63-95.
- B72 Walker, J.D. & Colwell, R.R. (1975). Degradation of hydrocarbons and mixed hydrocarbon substrate by microorganisms from Chesapeake Bay. *Progr. Wat. Technol.* 7, 783-791.
- B73 Walker, J.D. & Colwell, R.R. (1976). Measuring the potential activity of hydrocarbon-degrading bacteria. *Appl. Microbiol.* 31, 189-197.
- B74 Walker, J.D. & Colwell, R.R. (1976). Enumeration of petroleum-degrading microorganisms. *Appl. envir. Microbiol.* 31, 198-207.
- B75 Walker, J.D. & Colwell, R.R. (1976). Oil, mercury and bacterial interactions. *Envir. Sci. Technol.* 10, 1145-1147.
- B76 Walker, J.D. & Colwell, R.R. (1977). Role of autochthonous bacteria in the removal of spilled oil from sediment. *Envir. Pollut.* 12, 51-56.
- B77 Walker, J.D. & Colwell, R.R. (1977). Sampling device for monitoring biodegradation of oil and other pollutants in aquatic environments. *Envir. Sci. Technol.* 11, 93-95.
- B78 Walker, J.D., Colwell, R.R. & Petrakis, I. (1975). Degradation of petroleum by an alga, *Prototheca zopfii*. *Appl. Microbiol.* 30, 79-81.

- B79 Walker, J.D., Colwell, R.R. & Petrakis, I. (1975). Evaluation of petroleum degrading potential of bacteria from water and sediment. *Appl. Microbiol.* 30, 1036-1039.
- B80 Walker, J.D., Colwell, R.R. & Petrakis, L. (1975). Microbial petroleum degradation: application of computerized mass spectrometry. *Can. J. Microbiol.* 21, 1760-1767.
- B81 Walker, J.D., Colwell, R.R. & Petrakis, L. (1975). Bacterial degradation of motor oil. *J. Wat. Pollut. Control Fed.* 47, 2058-2066.
- B82 Walker, J.D., Colwell, R.R. et al. (1975). Petroleum-degrading achlorophyllous alga *Prototheca zopfii*. *Nature, Lond.* 254, 423-424.
- B83 Walker, J.D., Petrakis, L. & Colwell, R.R. (1976). Comparison of the biodegradability of crude and fuel oils. *Can. J. Microbiol.* 22, 598-602.
- B84 Ward, D.M. & Brock, T.D. (1975). Oil biodegradation in Lake Mendota, Wisconsin. Limitation by oxygen and organic matter. (Abstract only). *Abstr. a. Meet. Am. Soc. Microbiol.* 75, 127.
- B85 Ward, D.M. & Brock, T.D. (1976). Environmental factors influencing the rate of hydrocarbon oxidation in temperate lakes. *Appl. envir. Microbiol.* 31, 764-772.
- B86 Ward, D.M. & Brock, T.D. (1976). Nutrient limitation of oil biodegradation in lakes of varying water quality in Vilas County. *Trans. Wis. Acad. Sci. Arts Lett.* 64, 240-249.
- B87 Water Research Association (1974). *Ground water pollution in Europe*. Proceedings of a Conference, Reading, 1972. Fort Washington, N.Y. Water Information Center.
- B88 Watkinson, R.J. (ed.) (1978). *Developments in biodegradation of hydrocarbons*. London, Applied Science Publishers. 232 pp.
- B89 Whelan, T., Ishmael, J.T. & Bishop, W.S. (1976). Long-term chemical effects of petroleum in South Louisiana wetlands. 1. Organic carbon in sediments and waters. *Mar. Pollut. Bull.* 7, 150-155.
- B90 Zajic, J.E., Supplisson, B. & Volesky, B. (1974). Bacterial degradation and emulsification of No. 6 fuel oil. *Envir. Sci. Technol.* 8, 664-668.
- B91 Zobell, C.E. (1962). The occurrence, effects and fate of oil polluting the sea. *Int. Conf. Wat. Pollut. Res.*, Church House, Westminster, Lond., 3-7 Sept. 3 Pap. 48, 27 pp.

Section C. General Occurrence, Properties

- C1 Andelman, J.B. & Snodgrass, J.E. (1974). Incidence and significance of polynuclear aromatic hydrocarbons in the water environment. *Crit. Rev. envir. Control*, 4, 69-83.
- C2 Blumer, M., Ehrhardt, M. & Jones, J.H. (1973). The environmental fate of stranded crude oil. *Deep-Sea Res.* 20, 239-259.
- C3 Brassell, S.C., Eglinton, G. et al. (1978). Natural background of alkanes in the aquatic environment. In: *Aquatic pollutants: transformation and biological effects*. Proc. 2nd int. Symp. aquat. Pollut., Noordurjkerhaut, 1977 (eds O. Hutzinger, I.H. Van Lelyveld, & B.C.J. Zoetman). Oxford, Pergamon, 69-86.
- C4 Duffey, E. (1964). The Norfolk Broads: a regional study of wildlife conservation in a wetland area with high tourist attraction. *Publs int. Un. Conserv. Nat. N.S.*, 3, 290-301.
- C5 Environmental Protection Agency, Water Quality Office (1970). *Water quality criteria data book, Vol 1. Organic chemical pollution of fresh water*. Washington, DC, EPA 379 pp.
- C6 Giger, W., Reinhard, M. et al. (1974). Petroleum-derived and indigenous hydrocarbons in recent sediments of Lake Zug, Switzerland. *Envir. Sci. Technol.* 8, 454-455.
- C7 Harrison, R.M., Perry, R. & Wellings, R.A. (1976). Effect of water chlorination upon levels of some polynuclear aromatic hydrocarbons in water. *Envir. Sci. Technol.* 10, 1151-1156.
- C8 Hellmann, H. (1974). Detection and present extent of mineral oil pollution in our surface waters. *Wasserwirtschaft, Stuttg.* 64, 218-222. (German with English summary)
- C9 Hellmann, H. & Holeczek, M. (1974). Hydrocarbons in (aerobic) sediments in inland waters of the German Federal Republic. *Dt. gewas-serk. Mitt.* 18, 4, 96-100. (German with English summary).
- C10 Hites, R.A. & Biemann, K. (1972). Water pollution: organic compounds in the Charles River, Boston. *Science, N.Y.* 178, 158-160.
- C11 Hunter, J.V., Allen, H.C. & Shelton, T.B. (1970). Benthic decomposition of adsorbed oil pollutants. New Brunswick, N.J. Wat. Resour. Res. Inst., Rutgers Univ., 31 pp. (Eutrophication Abstracts 1971, No. 2514).
- C12 Laflamme, R.E. & Hites, R.A. (1978). The global distribution of polycyclic aromatic hydrocarbons in recent sediments. *Geochim. cosmochim. Acta*, 42, 289-303.
- C13 Levy, E.M. (1971). The presence of petroleum residues off the east coast of Nova Scotia, in the Gulf of St. Lawrence, and the St. Lawrence River. *Wat. Res.* 5, 723-733.
- C14 Levy, E.M. & Walton, A. (1973). Dispersed and particulate petroleum residues in the Gulf of St. Lawrence. *J. Fish. Res. Bd Can.* 30, 261-267.
- C15 Lindsay, J.T. & Prather, B.V. (1977). Solving petroleum refinery wastewater problems. *J. Wat. Pollut. Control Fed.* 49, 1779-1785.



- C16 Literathy, P. (1975). Study of river pollution caused by micropollutants. *Wat. Res.* 9, 1001-1003.
- C17 Lysyj, I. & Russell, E.C. (1974). Dissolution of petroleum derived products in water. *Wat. Res.* 8, 863-868.
- C18 Mallet, L. (1965). Presence of hydrocarbons of the benzopyrene type in the sediments near the bank of the Seine downstream from Paris. *Bull. Acad. natn. Méd.* 149, 656-660.
- C19 Martin, A.E. (1971). Water pollution by oil - some health considerations. In: *Water pollution by oil* (ed. P. Hepple), London, Institute of Petroleum. 153-164.
- C20 Matis, J.R. (1971). Petroleum contamination of ground water in Maryland. *Ground Wat.* 9, 57-75.
- C21 Meijers, A.P. (1973). Organic micro-pollutants in the rivers Rhine and Meuse in 1972. *H<sub>2</sub>O*, 6, 244-249.
- C22 Meijers, A.P. & Leer, R.C. (1976). The occurrence of organic micro-pollutants in the River Rhine and the River Maas in 1974. *Wat. Res.* 10, 597-604.
- C23 Meyers, P. (1976). Cycling: petroleum hydrocarbons: crude oil, refined products and waste products: sediments - sources or sinks for petroleum hydrocarbons? In: *Sources, effects and sinks of hydrocarbons in the aquatic environment*. Symposium, Washington DC, 1976. Arlington, Va, Am. Inst. biol. Sci., 309-324.
- C24 Phillips, C.R. & Groseva, V.M. (1977). The spreading of crude oil spills across a lake. *Wat. Air Soil Pollut.* 8, 353-360.
- C25 Pochkin, Yu. N. & Massino, O.A. (1968). The contamination of open inland waters with petroleum products. *Kazan. med. Zh.* 3, 81-83. (Russian)
- C26 Spiker, E.C. & Ruben, M. (1975). Petroleum pollutants in surface and ground water as indicated by the carbon-14 activity of dissolved organic carbon. *Science, N.Y.* 187, 61-64.
- C27 Starnes, P.K. & Brown, C.A. (1976). Hydrocarbons in a wilderness lake. *Mar. Pollut. Bull.* 7, 131-132.
- C28 Suess, M.J. (1976). The environmental load and cycle of polycyclic aromatic hydrocarbons. *Sci. Total Envir.* 6, 239-250.
- C29 Thueer, M. & Stumm, W. (1977). Sedimentation of dispersed oil in surface waters. *Prog. Wat. Technol.* 9, 183-194.
- C30 Toms, R. (1975). Oil pollution of inland waters in England and Wales. In: *Proc. Conf. Prevention and control of oil pollution*, San Francisco, 1975, 23-28.
- C31 Van der Waarden, M., Bridie, A.L.A.M. & Groenewoud, W.M. (1971). Transport of mineral oil components to ground water: I. Model experiments on the transfer of hydrocarbons from a residual oil zone to trickling water. *Wat. Res.* 5. 213-226.
- C32 Wakeham, S.G. (1976). A comparative survey of petroleum hydrocarbons in lake sediments. *Mar. Pollut. Bull.* 7, 206-211.
- C33 Wakeham, S.G. & Carpenter, R. (1976). Aliphatic hydrocarbons in sediments of Lake Washington. *Limnol. Oceanogr.* 21, 711-723.

- C34 Whipple, W., Hunter, J.V. & Shaw, L.U. (1976). Hydrocarbon in sewage and urban runoff - Delaware Estuary. In: *Sources, effects and sinks of hydrocarbons in the aquatic environment*. Symposium, Washington DC. Arlington, Va, Am. Inst. biol. Sci. 55-65.
- C35 Zurcher, F. & Thuer, M. (1978). Rapid weathering processes of fuel oil in natural waters. Analyses and interpretations. *Envir. Sci. Technol.* 12, 838-843.
- C36 Zyl'kina, V. Ya. (1975). Importance of suspended solids and bottom sediments in the self-purification of the Selenga River from petroleum products. *Hydrobiol. J.* 11, 3, 53-59.

#### Section D.        Methods

- D1 Basu, D.K. & Saxena, J. (1978). Monitoring of polynuclear aromatic hydrocarbons in water. II. Extraction and recovery of six representative compounds with polyurethane foams. *Envir. Sci. Technol.* 12, 791-795.
- D2 Curtis, M.L. (1977). Use of pattern recognition techniques for typing and identification of oil spills. *National Technical Information Service, Report No. AD-A045/802*, 248 pp. Springfield, Va.
- D3 Das, B.S. & Thomas, G.H. (1978). Fluorescence detection in high-performance liquid chromatographic determination of polycyclic aromatic hydrocarbons. *Analyt. Chem.* 50, 967-973.
- D4 Dell'Acqua, R., Egan, J.A. & Bush, B. (1975). Identification of petroleum products in natural water by gas chromatography. *Envir. Sci. Technol.* 9, 38-41.
- D5 Desbaumes, E. & Imhoff, C. (1972). Determination of hydrocarbon residues in water. *Wat. Res.* 6, 885-893.
- D6 Duckworth, D.F. (1971). Aspects of petroleum pollutants analysis. In: *Water pollution by oil* (ed. P. Hepple), London. Institute of Petroleum. 165-179.
- D7 Fielding, M. (1972). Analysis of oil pollutants in surface waters. *Tech. Pap. Wat. Res. Ass.*, TP94, 57 pp.
- D8 Giger, W. & Blumer, M. (1974). Polycyclic aromatic hydrocarbons in the environment: isolation and characterization by chromatography, visible, ultraviolet and mass spectrometry. *Analyt. Chem.* 46, 1663-1671.
- D9 Giger, W. & Schaffner, C. (1978). Determination of polycyclic aromatic hydrocarbons in the environment by glass capillary gas chromatography. *Analyt. Chem.* 50, 243-249.

- D10 Goma, G. & Durand, G. (1971). Determination of immiscible substances by gas chromatography: hydrocarbons in water. *Wat. Res.* 5, 545-552.
- D11 Goolsby, A.D. (1971). Continuous monitoring of water surfaces for oil films by reflectance measurements. *Envir. Sci. Technol.* 5, 356-357.
- D12 Hagenmaier, H., Feirabend, R. & Jager, W. (1977). Determination of polycyclic aromatic hydrocarbons in water by means of high pressure liquid chromatography. *Z. Wass. Abwass. Forsch.* 10, 99-104. (German)
- D13 Hargrave, B.T. & Phillips, G.A. (1975). Estimates of oil in aquatic sediments by fluorescence spectroscopy. *Envir. Pollut.* 8, 193-216.
- D14 Hellmann, H. (1973). With which analytic methods can mineral oil pollution be traced to its source? *Vom Wass.* 41, 45-64.
- D15 Hertz, H.S., May, W.E. et al. (1976). Petroleum analysis: methodology for quantitative and qualitative assessment of oil spill. *Envir. Sci. Technol.* 10, 900-903.
- D16 Hunter, L. (1975). Quantitation of environmental hydrocarbons by thin layer chromatography. Gravimetry/densitometry comparison. *Envir. Sci. Technol.* 9, 241-246.
- D17 Jeltès, R., Burghardt, E. et al. (1977). Application of capillary gas chromatography in the analysis of hydrocarbons in the environment. *Chromatographia*, 10, 430-437.
- D18 Jeltès, R. & Tonkelaar, W.A.M. (1972). Gas chromatography versus infra-red spectrometry for determination of mineral oil dissolved in water. *Wat. Res.* 6, 271-278.
- D19 Kawahara, F.K. (1969). Identification and differentiation of heavy residual oil and asphalt pollutants in surface waters by comparative ratios of 1 R absorbances. *Envir. Sci. Technol.* 3, 150-153.
- D20 Kawahara, F.K. & Yang, Y.Y. (1976). Systems chemical analysis of petroleum pollutants. *Analyt. Chem.* 48, 651-654.
- D21 Kuznetsova, Z.I. (1967). Use of radioautography in determining the number of hydrocarbon oxidizing bacteria in underground waters. *Mikrobiologiya*, 36, 529-534. (Russian with English summary)
- D22 Lee, C.C., Craig, W.K. & Smith, P.T. (1974). Water soluble hydrocarbons from crude oil. *Bull. envir. Contam. Toxic.* 12, 212-217
- D23 Lee, E.G.H. & Walden, C.C. (1970). A rapid method for the estimation of trace amounts of kerosene in effluents. *Wat. Res.* 4, 641-644.
- D24 Lysyj, I. & Newton, P.R. (1972). Multicomponent pattern recognition and differentiation method: analysis for oil in natural waters. *Analyt. Chem.* 44, 2385-2387.
- D25 Mair, B.J. (1964). Hydrocarbons isolated from petroleum. *Oil Gas J.*, Sep. 14, 130-134.
- D26 Mallevialle, J. (1974). Measurement of hydrocarbons in water: application to cases of surface water pollution. *Wat. Res.* 8, 1071-1075.
- D27 Malueg, N.J. & Krawczyk, D.F. (1973). Tracing oil as a pollutant in water. *J. Petrol. Technol.* 25, 243-248.



- D28 Mattson, J.S., Mattson, C.S. et al. (1977). Multivariate statistical approach to the finger printing of oils by infrared spectrometry. *Analyt. Chem.* 49, 297-302.
- D29 McLee, A.G. & Wayman, M. (1971). Measurement of methane, n-butane and carbon dioxide in aqueous solution. *Lab. Pract.* 20, 711-712.
- D30 Miles, D.H., Coign, M.J. & Brown, L.R. (1977). A liquid chromatographic fluorescence technique for estimating crude oil in water, sediment and biological material. In: *Proc. 1977 Oil Spill Conf. (prevention, behaviour, control, cleanup)*. Washington DC, Am. Petrol. Inst. 179-182.
- D31 Miller, J.W. (1973). A multiparameter oil pollution source identification system. *U.S. envir. Prot. Ag., envir. Prot. Technol. Ser.*, EPA-R2-73-221.
- D32 Rasmussen, D.V. (1976). Characterization of oil spills by capillary column gas chromatography. *Analyt. Chem.* 48, 1562-1566.
- D33 Saner, W.A. & Fitzgerald, G.E. (1976). Thin-layer chromatographic techniques for identification of water-borne petroleum oils. *Envir. Sci. Technol.* 10, 893-897.
- D34 Saxena, J., Kozuchowski, J. & Basu, D.K. (1977). Monitoring of polynuclear aromatic hydrocarbons in water: 1. Extraction and recovery of benzo(a) pyrene with porous polyurethane foam. *Envir. Sci. Technol.* 11, 682-685.
- D35 Wakeham, S.G. (1977). Synchronous fluorescence spectroscopy and its application to indigenous and petroleum-derived hydrocarbons in lacustrine sediments. *Envir. Sci. Technol.* 11, 272-276.
- D36 Walker, J.D., Colwell, R.R. et al. (1974). Extraction of petroleum hydrocarbons from oil contaminated sediments. *Bull. envir. Contam. Toxic.* 13, 245-248.
- D37 Whittle, P.J. (1977). Identification of hydrocarbon markers in oil-polluted waters by use of column and thin-layer chromatography. *Analyst, Lond.* 102, 976-978.
- D38 Zitko, V. (1975). Aromatic hydrocarbons in aquatic fauna. *Bull. envir. Contam. Toxic.* 14, 621-631.

Section E. Causes, Sources

- E1 American Water Works Association (1966). Oil pollution of water supplies. Task Group report. *J. Am. Wat. Wks Ass.* 58, 813-821.
- E2 Anan'ev, N.I., Kyuregyan, A.A. & Rybina, L.A. (1975). Case of sub-surface water pollution by petroleum product wastes. *Gig. Sanit.*, 10, 97-98. (Russian)
- E3 Atkinson, L.P. (1974). Assessment of natural concentrations and man-made sources of low molecular weight hydrocarbons in Saanich Inlet. *Rep. natn. Sci. Fdn - Int. Decade Ocean Explor.* Controlled ecosystem pollution experiment (CEPEX), May 1, 1974 - May 1, 1975, Sect. 7.
- E4 Basu, D.K. & Saxena, J. (1978). Polynuclear aromatic hydrocarbons in selected U.S. drinking waters and their raw water sources. *Envir. Sci. Technol.* 12, 795-798.
- E5 Clean Environment Commission, Manitoba (1976). Preliminary report on contamination of underground water sources by refined petroleum products. *Ground Wat.* 14, 1, 36-44.
- E6 Cooper, B.S., Harris, R.C. & Thompson, S. (1974). Land-derived pollutant hydrocarbons. *Mar. Pollut. Bull.* 5, 15-16.
- E7 Cruchet, P. (1967). An accidental pollution caused by fuel oil. *Mbull. Schweiz. Ver. Gas-u. WassFachm.* 47, 67-68.
- E8 Davies, J.W., Harrison, R.M. et al. (1976). Municipal incinerator as source of polynuclear aromatic hydrocarbons in environment. *Envir. Sci. Technol.* 10, 451-453.
- E9 Dietrich, K.R. (1964). Investigations into the pollution of water by two-stroke outboard motors. *Gesundheitsingenieur*, 85, 342-347. (German)
- E10 Ditton, R.B. & Goodace, T.L. (1973). Water quality perception and the recreational uses of Green Bay, Lake Michigan. *Wat. Resour. Res.* 9, 569-579.
- E11 Ebershorst, R.E. (1965). The pollution of water by outboard motors. *Öst. Wasserw.* 17, 18-19.
- E12 Farrington, J.W. & Quinn, J.G. (1973). Petroleum hydrocarbons and fatty acids in wastewater effluents. *J. Wat. Pollut. Control Fed.* 45, 704-712.
- E13 Fielding, M. (1976). Oil pollution of inland waters. *Publ. Hlth Engr* 4, 18-22.
- E14 Fitzek, R. (1965). Flood water and oil pollution. *Mitt. Verein. dt. Gewässerschutz*, Jul.-Aug. 9.
- E15 George, M. (1972). The conservation of aquatic wildlife. Eastbourne Hlth Congr., R. Soc. Hlth, Lond., 138-141.
- E16 Hase, A. & Hites, R.A. (1976). On the origin of polycyclic aromatic hydrocarbons in the aqueous environment. In: *Identification and analysis of organic pollutants in water* (ed. L.H. Keith). Ann Arbor, Ann Arbor Publ. 205-214.

- E17 Hellmann, H. & Brons, F.J. (1970). Investigation into Rhine River hydrocarbon contents 1968/69 and reflections on their origin: a contribution to the question of water pollution by mineral oil. *Dt. gewässer Mitt.* 14, 14-21. (German with English summary).
- E18 Howard, H.H. & Stewart, R. (1968). Water pollution by outboard motors. *Conservationist*, June-Jul., 6-8 & 31.
- E19 Hunnefeld, G.R. (1966). Oil pollution in surface waters caused by the operation of outboard motors. *Dt. gewässer Mitt.*, 10, 57-59.
- E20 Ineson, J. (1964). Pollution of water and soil by miscellaneous petroleum products. British national report for Subject No. 2, *Int. Wat. Supply Congr.*, Stockholm, 1964, 20 pp.
- E21 Leach, G. (1970). Water supply threat from river oil slicks. *Br. Wat. Supply*, 3, 33-34.
- E22 Lehn, H. (1968). Movements of water in Lake Constance. A contribution on the possibilities of the spread of oil in Lake Constance. *Gas-u. WassFach*, 109, 89-94.
- E23 Livingstone, F.C. (1971). Combating the menace of oil in rivers. *Wat. Sewage Wks*, 118, 58-61.
- E24 Meynell, P.J. (1973). A hydrobiological survey of a small Spanish river grossly polluted by oil refinery and petrochemical wastes. *Freshwat. Biol.* 3, 503-520.
- E25 Myers, L.H. (1976). Sources and distribution of hydrocarbons in the environment. In: *Sources, effects and sinks of hydrocarbons in the aquatic environment*. Symposium, Washington DC, 1976. Arlington, Va. Am. Inst. biol. Sci. 66-83.
- E26 Nemerow, N.L. (1978). *Industrial water pollution. Origins, characteristics and treatment*. Addison-Wesley Publ. Co., Mass., Lond., 738 pp.
- E27 Osgood, J.O. (1974). Hydrocarbon dispersion in ground water: significance and characteristics. *Ground Wat.* 12, 427-436.
- E28 Shuster, W.W., Clesceri, L. et al. (1974). Effects of exhaust from two-cycle outboard engines. *U.S. envir. Prot. Ag., envir. Prot. Technol. Ser.*, EPA-670/2-74-063.
- E29 Toms, R.G. (1971). The threat to inland waters from oil pollution. In: *Water pollution by oil* (ed. P. Hepple). London. Institute of Petroleum. 13-20.
- E30 Trites, R.W. (1972). The Gulf of St. Lawrence from a pollution viewpoint. *Mar. Pollut. Sea Life*, FAO, 1972, 59-72.
- E31 Van Looche, R., De Borger, R. et al. (1975). Soil and ground water contamination by oil spills; problems and remedies. *Int. J. envir. Stud.* 8, 99-111.
- E32 Van Vleet, E.S. & Quinn, J.G. (1977). Input and fate of petroleum hydrocarbons entering the Providence River and Upper Narragansett Bay from wastewater effluents. *Envir. Sci. Technol.* 11, 1086-1092.
- E33 Vogel, H.E. (1968). Oil risks in Switzerland. *Gas-u. WassFach*, 109, 102-103.
- E34 Wakeham, S.G. (1977). A characterization of the sources of petroleum hydrocarbons in Lake Washington. *J. Wat. Pollut. Control Fed.* 49, 1680-1687.



- E35 Wakeham, S.G. (1977). Hydrocarbon budgets for Lake Washington. *Limnol. Oceanogr.* 22, 952-957.
- E36 Whipple, W. Jr., Hunter, J.V. & Yu, S.L. (1975). Projection of petroleum content of urban runoff. New Brunswick, N.J. 5 pp.
- E37 Zweig, G., Nair, J.H. & Compton, B. (1968). A study of fat and oil pollution of New York State waters. *Publ. Wks, N.Y.* 99, 148-152.

#### Section F. Treatment

- F1 Blokker, P.C. (1971). Prevention of water pollution from refineries. In: *Water pollution by oil* (ed. P. Hepple) London. Institute of Petroleum. 21-36.
- F2 Eckoldt, M. (1967). Methods used for the treatment of surface waters polluted by oil. *Dt. gewasserk. Mitt.* 11, 105-109.
- F3 Eckoldt, M. (1967). The treatment of oil-polluted waters. *VDI Nachr.* 21, 18, 1.
- F4 Gloyna, E.F., Brady, S.O. & Pereda, P.M. (1971). Separation of oil from waste waters with crushed graphite ore. In: *Proc. 26th ind. Waste Conf., Purdue Univ.*, 308-317.
- F5 Guntz, G.D. & Meloy, T.P. (1973). Oil recovery system using sorbent material. *U.S. envir. Prot. Ag., envir. Prot. Technol. Ser.*, EPA-670/2-73-068.
- F6 Harrison, R.M., Perry, K. & Wellings, R.A. (1976). Chemical kinetics of chlorination of some polynuclear aromatic hydrocarbons under conditions of water treatment processes. *Envir. Sci. Technol.* 10, 1156-1160.
- F7 Hellmann, H. & Knopp, H. (1966). Further investigations into the suitability of emulsifying agents for removal of oil from waters. *Dt. gewasserk. Mitt.* 11, 91-95.
- F8 Jacob, B.L. (1974). North Fork alluvial decontamination project, Hubbard Creek Reservoir watershed. *U.S. envir. Prot. Ag., envir. Prot. Technol. Ser.*, EPA-660/2-74-019.
- F9 Jerbo, A. (1973). Cleanup of inland oilspills. *Vatten*, 29, 223-232.
- F10 Kaspar, H., Leidner, H. & Wuhrmann, K. (1976). Removal of petroleum hydrocarbons in activated sludge plants. *Gas-u. WassFach*, 117, 400-405. (German).

- F11 Madia, J.R., Fruh, S.M. et al. (1976). Granular packed bed coalescer: influence of packing wettability on coalescence. *Envir. Sci. Technol.* 10, 1044-1046.
- F12 Pedroli, R. (1974). Transfrontier problems of freshwater conservation, especially in the Rhine and Lake Geneva. *Naturoipa*, 20, 7-11.
- F13 Tischler, L.F., Elton, R.L. & Ford, D.L. (1977). Determining the effect of petroleum hydrocarbons on aqueous environments. *Ind. Wastes*, 23, 6, 20-24.
- F14 Van Loocke, R., De Borger, R. et al. (1975). Soil and groundwater contamination by oil spills; problems and remedies. *Int. J. envir. Stud.* 8, 99-111.
- F15 Williams, D.E. & Wilder, D.G. (1971). Gasoline pollution of a ground water reservoir: a case history. *Ground Wat.* 9, 6, 50-56.

#### Section G. Carcinogenesis

- G1 Borneff, J. & Kunte, H. (1965). Cancerogenic substances in water and soil. XVII. The occurrence and the origin and evaluation of polycyclic aromatic hydrocarbons in water. *Arch. Hyg. Bakt.* 149, 226-243. (German with English summary)
- G2 Il'nitskii, A.P. & Rozhkova, L.G. (1970). Pollution of reservoirs by carcinogenic hydrocarbons. *Vop. Onkol.* 16, 7, 78-82. (Russian with English summary)
- G3 Klubkov, V.G. (1977). Role of navigation in pollution of freshwater bodies by carcinogenic hydrocarbons. *Wat. Resour.* 4, 442-445.
- G4 Lewis, N.M. (1975). Polynuclear aromatic hydrocarbons in water. *Wat. Treat. Exam.* 24, 243-277.
- G5 Reichert, J., Kunte, H. et al. (1971). Carcinogenic substances occurring in water and soil: XVIII. Further studies on the elimination from waste water of carcinogenic polycyclic aromatic hydrocarbons. *Zentbl. Bakt. Parasitkde, Abt. Orig. Reihe B.* 155, 18-40.

Section H.      Soil

- H1 Antoniewski, J. & Schaefer, R. (1972). The microbiology of hydrocarbon impregnated soils: changes in respiratory activity. *Annls Inst. Pasteur, Paris*, 123, 805-819. (French with English summary).
- H2 Cresswell, L.W. (1977). The fate of petroleum in a soil environment. In: *Proc. 1977 Oil Spill Conf. (prevention, behaviour, control, cleanup)*. Washington DC. Am. Petrol. Inst. 479-482.
- H3 Dietz, D.N. (1973). Behaviour of components from spilled oil on their way through the soil. *J. Petrol. Technol.* 25, 1045-1046.
- H4 Gudin, C. & Syrratt, W.J. (1975). Biological aspects of land rehabilitation following hydrocarbon contamination. *Envir. Pollut.* 8, 107-112.
- H5 Jensen, V. (1977). Effects of lead on biodegradation of hydrocarbons in soil. *Oikos*, 28, 220-224.
- H6 Jones, J.G. (1969). The determination of microbial hydrocarbon metabolism in natural environments. *Arch. Mikrobiol.* 67, 397-407.
- H7 Jones, J.G. & Edington, M.A. (1968). An ecological survey of hydrocarbon oxidizing micro-organisms. *J. gen. Microbiol.* 52, 381-390.
- H8 Kincannon, L.B. (1972). Oily waste disposal by soil cultivation process. *U.S. envir. Prot. Ag., envir. Prot. Technol. Ser.*, EPA-R2-72-110.
- H9 Lehtomaki, M. & Niemela, S. (1975). Improving microbial degradation of oil in soil. *Ambio*, 4, 126-129.
- H10 Llanos, C. & Kj  ller, A. (1976). Changes in the flora of soil fungi following oil waste application. *Oikos*, 27, 377-382.
- H11 Raisbeck, J.M. & Mohtadi, M.F. (1974). The environmental impacts of oil spills on land in the Arctic regions. *Wat. Air Soil Pollut.* 3, 195-208.
- H12 Stebbings, R.E. (1970). Recovery of saltmarsh in Brittany 16 months after heavy pollution by oil. *Envir. Pollut.* 1, 163-169.
- H13 Westlake, D.W.S., Jobson, A.M. & Cook, F.D. (1978). In situ degradation of oil in a soil of the boreal region of the Northwest Territories. *Can. J. Microbiol.* 24, 254-260.



## 5. ACKNOWLEDGEMENTS

Much of this work was carried out under Contract DGR/480/518 with the Department of the Environment.

We are very grateful to members of the library staff at the Marine Biological Association, Plymouth, and the Water Research Centre, Medmenham, for allowing access to material collected in their own literature searches; to Mrs Doreen Fishwick for typing the original report; to Mrs Kathleen Pearson for compiling the author index; and to Mrs Joyce Hawksford for typing the camera copy for this publication.

## 6. AUTHOR INDEX

By first author only. References are to *sections*: within each section references are arranged alphabetically by author.

| <i>Author</i>                          | <i>Section</i> | <i>Author</i>                               | <i>Section</i> |
|----------------------------------------|----------------|---------------------------------------------|----------------|
| Ackman, R.G. & Noble 1973              | A1             | Breuil, C. & Shindler 1977                  | B9             |
| Adams, E.S. 1975                       | A2             | Brodersen, C.C., Rice et al. 1977           | A17            |
| Ahearn, D.G. & Meyers 1976             | B1             | Brooks, J.M., Fryxell et al. 1977           | A18            |
| American Water Works Association 1966  | E1             | Brown, E.R., Hazdra et al. 1973             | A19            |
| Anan'ev, N.I., Kyuregyan & Rybina 1975 | E2             | Brown, L.R. & Tischer 1969                  | B10            |
| Andelman, J.B. & Snodgrass 1974        | C1             | Bunch, J.N. & Harland 1976                  | B11            |
| Anderson, J.W. 1977                    | A3             | Burk, C.J. 1977                             | A20            |
| Anderson, J.W. & Neff, 1975            | A4             | Bury, R.B. 1972                             | A21            |
| Antoniewski, J. & Schaefer 1972        | H1             | Button, D.K. 1974                           | B12            |
| Atkinson, L.P. 1974                    | E3             | Calder, J.A. & Lader 1976                   | A22            |
| Atlas, R.M. 1975                       | B2             | Chater, K.W.A. & Somerville (eds.) 1978     | B13            |
| Atlas, R.M. 1977                       | B3             | Chet, I. & Mitchell 1976                    | A23            |
| Atlas, R.M. & Schofield 1975           | B4             | Clark, R.C. Finley & Gibson 1974            | A24            |
| Atlas, R.M., Schofield et al. 1976     | A5             | Clean Environment Commission, Manitoba 1976 | E5             |
| Baier, R.E. 1972                       | B5             | Colwell, R.R. Walker & Nelson 1973          | B14            |
| Baker, J.M. 1970                       | A6             | Conrad, B.F., Walker & Colwell 1976         | B15            |
| Baker, J.M. 1978                       | A7             | Cooper, B.S., Harris & Thompson 1974        | E6             |
| Barnett, J. & Toews 1978               | A8             | Cooper, J.M. & Wilhm 1975                   | A25            |
| Bartha, R. & Atlas 1973                | B6             | Copeland, B.J. & Dorris 1964                | A27            |
| Basu, D.K. & Saxena 1978a              | D1             | Corner, E.D.S. 1975                         | A27            |
| Basu, D.K. & Saxena 1978b              | E4             | Corner, E.D.S., Harris et al. 1976          | A28            |
| Batterton, J.C. 1977                   | A9             | Cresswell, L.W. 1977                        | H2             |
| Baumgardner, R.K. 1966                 | A10            | Crocker, A.D., Cronshaw & Holmes 1974       | A29            |
| Beam, H.W. & Perry 1974                | B7             | Crocker, A.D., Cronshaw & Holmes 1975       | A30            |
| Bengtsson, L. & Bergren 1972           | A11            | Crow, S.A., Myers & Ahearn 1974             | B16            |
| Berlin, J.A. & Micks 1973              | A12            | Cruchet, P. 1967                            | E7             |
| Berry, W.O. & Brammer 1977             | A13            | Curtis, M.L. 1977                           | D2             |
| Berry, W.O., Brammer & Bee 1978        | A14            |                                             |                |
| Blokker, P.C. 1971                     | F1             |                                             |                |
| Blumer, M., Ehrhardt & Jones 1973      | C2             |                                             |                |
| Blundo, R. 1978                        | A15            |                                             |                |
| Bohonos, N., Chout & Spanggord 1977    | B8             |                                             |                |
| Borneff, J. & Kunte 1965               | G1             |                                             |                |
| Bott, T.L. & Rogenmuser 1978           | A16            | Das, B.S. & Thomas 1978                     | D3             |
| Brassell, S.C., Eglinton et al. 1978   | C3             | Danavin, I.A., Mironov & Tsimbal 1975       | A31            |

| Author                                                                              | Section | Author                                      | Section |
|-------------------------------------------------------------------------------------|---------|---------------------------------------------|---------|
| Davidson, I.E. 1972                                                                 | A32     | Geraci, J.R. & Smith 1976                   | A47     |
| Davies, J.S. & Westlake 1979                                                        | B17     | Gibbs, C.F. 1976                            | B23     |
| Davies, J.W., Harrison et al.<br>1976                                               | E8      | Gibbs, C.F. 1976                            | B24     |
| Dean-Raymond, D. & Bartha 1974                                                      | B18     | Gibson, D.T. 1977                           | B25     |
| Dell'Acqua, R., Egan & Bush<br>1975                                                 | D4      | Giger, W. & Blumer 1974                     | D8      |
| Dennington, V.N., George &<br>Wyborn 1975                                           | A33     | Giger, W., Reinhard et al 1974              | C6      |
| Department of the Environment,<br>Central Unit on Environ-<br>mental Pollution 1976 | A34     | Giger, W. & Schaffner 1978                  | D9      |
| Desbaumes, E. & Imhoff 1972                                                         | D5      | Gilewicz, M., Zacek et al.<br>1979          | B26     |
| De Vries, A.L. 1976                                                                 | A35     | Gloyna, E.F., Brady & Pereda<br>1971        | F4      |
| Dietrich, K.R. 1964                                                                 | E9      | Goma, G. & Durand 1971                      | D10     |
| Dietz, A.S., Tuominen &<br>Albright 1976                                            | A36     | Goolsby, A.D. 1971                          | D11     |
| Dietz, D.N. 1978                                                                    | B19     | Gordon, D.C. & Prouse 1973                  | A48     |
| Dietz, D.N. 1973                                                                    | H3      | Groenewegen, D. & Stolp 1976                | B27     |
| Disalvo, L.H., Guard et al.<br>1973                                                 | A37     | Gudin, C. & Syratt 1975                     | H4      |
| Ditton, R.B. & Goodace 1973                                                         | E10     | Gumtz, G.D. & Meloy 1973                    | F5      |
| Dixit, D. & Anderson 1977                                                           | A38     | Hagenmaier, H., Feirabend &<br>Jager 1977   | D12     |
| Duckworth, D.F. 1971                                                                | D6      | Hanna, B.M., Hellebust &<br>Hutchinson 1975 | A49     |
| Duffey, E. 1964                                                                     | C4      | Hansen, W.G., Bitton et al.<br>1977         | B28     |
| Dunstan, W.M., Atkinson &<br>Natoli 1975                                            | A39     | Hargrave, B.T. & Phillips 1975              | D13     |
| Ebershorst, R.E. 1965                                                               | E11     | Harrison, R.M., Perry &<br>Wellings 1976    | C7      |
| Eckoldt, M. 1967                                                                    | F2      | Harrison, R.M., Perry &<br>Wellings 1976    | F6      |
| Eckoldt, M. 1967                                                                    | F3      | Hase, A. & Hites 1976                       | E16     |
| English, J.N., McDermott &<br>Henderson 1963                                        | A40     | Hellebust, J.A., Hanna et al.<br>1975       | A50     |
| English, J.N., Surber &<br>McDermott 1963                                           | A41     | Hellmann, H. 1973                           | D14     |
| Environmental Protection Agency<br>Water Quality Office 1970                        | C5      | Hellmann, H. 1974                           | C8      |
| Ereditario, J.M. & Pfaender<br>1977                                                 | A42     | Hellmann, H. & Brons 1970                   | E17     |
| Farrington, J.W. & Quinn 1973                                                       | E12     | Hellmann, H. & Holeczek 1974                | C9      |
| Fasoli, U. & Numann 1973                                                            | B20     | Hellmann, H. & Knopp 1966                   | F7      |
| Field Studies Council 1968                                                          | A43     | Herbes, S.E. 1977                           | A51     |
| Fielding, M. 1972                                                                   | D7      | Herbes, S.E. & Schwall 1978                 | B29     |
| Fielding, M. 1976                                                                   | E13     | Herbes, S.E., Schwall &<br>Williams 1977    | B30     |
| Finnerty, W.R., Kennedy et al.<br>1973                                              | B21     | Hertz, H.S., May et al. 1976                | D15     |
| Fitzek, R. 1965                                                                     | E14     | Higgins, I.J. & Gilbert, 1978               | B31     |
| Floodgate, G.D. 1972                                                                | B22     | Hites, R.A. & Biemann 1972                  | C10     |
| Forns, J.M. 1977                                                                    | A44     | Hodgins, H.O. Gronlund et al.<br>1977       | A52     |
| Fucik, K.W., Armstrong &<br>Neff 1977                                               | A45     | Hodson, R.E., Azam & Lee 1975               | A53     |
| George, J.D. 1971                                                                   | A46     | Hoehn, R.C. Stauffer et al.<br>1974         | A54     |
| George, M. 1972                                                                     | E15     | Hood, M.A., Bishop et al. 1975              | B32     |
|                                                                                     |         | Horowitz, A. & Atlas 1977                   | A55     |
|                                                                                     |         | Horowitz, A. & Atlas 1977                   | B33     |
|                                                                                     |         | Howard, H.H. & Stewart 1968                 | E18     |
|                                                                                     |         | Hughes, D.E. & McKenzie 1975                | B34     |
|                                                                                     |         | Hughes, D.E. & Stafford 1976                | B35     |



| Author                              | Section | Author                               | Section |
|-------------------------------------|---------|--------------------------------------|---------|
| Hunnefeld, G.R. 1966                | E19     | Laflamme, R.E. & Hites 1978          | C12     |
| Hunter, J.V., Allen & Shelton 1970  | C11     | Larock, P.A. & Ahlfeld 1973          | B42     |
| Hunter, L. 1975                     | D16     | Larson, R.A., Hunt & Blakenship 1977 | A71     |
| Hyland, J.L. & Schneider 1976       | A56     | Lawler, G.C., Loong & Laseter 1978   | A72     |
| Idoniboye-Obu, B. 1977              | A57     | Lawler, G.C., Loong & Laseter 1978   | A73     |
| Il'nitskii, A.P. & Rozhkova 1970    | G2      | Leach, G. 1970                       | E21     |
| Ineson, J. 1964                     | E20     | Lee, C.C., Craig & Smith 1974        | D22     |
| Jackivicz, T.P. & Kuzminski 1973    | A58     | Lee, E.G.H. & Walden 1970            | D23     |
| Jackivicz, T.P. & Kuzminski 1973    | A59     | Lee, R.F. 1977                       | A74     |
| Jacob, B.L. 1974                    | F8      | Lee, R.T. 1976                       | B43     |
| Jahn, W. 1972                       | A60     | Lehn, H. 1968                        | E22     |
| Jeltes, R., Burghardt et al. 1977   | D17     | Lehtomaki, M. & Niemela 1975         | H9      |
| Jeltes, R. & Tonkelaar 1972         | D18     | Levy, E.M. 1971                      | C13     |
| Jensen, V. 1977                     | H5      | Levy, E.M. & Walton 1973             | C14     |
| Jerbo, A. 1973                      | F9      | Lewis, N.M. 1975                     | G4      |
| Jobson, A., Cook & Westlake 1972    | B36     | Lindsay, J.T. & Prather 1977         | C15     |
| Johnston, R. 1970                   | B37     | Literathy, P. 1975                   | C16     |
| Jones, J.G. 1969                    | H6      | Liu, D.L. & Dutka 1973               | B45     |
| Jones, J.G. & Edington 1968         | H7      | Liu, D.L.S. 1973                     | B44     |
| Kaplin, V. & Kolesnikova 1971       | B38     | Livingstone, F.C. 1971               | E23     |
| Kappeler, T. & Wuhrmann 1978        | B39     | Llanos, C. & Kj  ller 1976           | H10     |
| Kappeler, T. & Wuhrmann 1978        | B40     | Lockwood, A.P.M. (ed.) 1976          | A75     |
| Kaspar, H., Leidner & Wuhrmann 1976 | F10     | Logan, J.W.M. & Perkins 1972         | A76     |
| Kator, H., Oppenheimer & Miget 1971 | B41     | Lysyj, I. & Newton 1972              | D24     |
| Kauss, P.B. & Hutchinson 1975       | A61     | Lysyj, I. & Russell 1974             | C17     |
| Kauss, P.B. & Hutchinson 1975       | A62     | Mackie, P.R., McGill & Hardy 1972    | A77     |
| Kauss, P. Hutchinson et al. 1973    | A63     | Madia, J.R., Fruh et al. 1976        | F11     |
| Kawahara, F.K. 1969                 | D19     | Mair, B.J. 1964                      | D25     |
| Kawahara, F.K. & Yang 1976          | D20     | Maksimov, V.N. 1977                  | A78     |
| Kempf, T., Ludemann & Pflaum 1967   | A64     | Malins, D.C., Hodgens & Weber 1976   | A79     |
| Kincannon, L.B. 1972                | H8      | Mallet, L. 1965                      | C18     |
| Klubkov, V.G. 1977                  | G3      | Mallevialle, J. 1974                 | D26     |
| Koroleva, A.M. 1977                 | A65     | Malueg, N.J. & Krawczyk 1973         | D27     |
| Kravchenko, M.E. & Gapochka 1977    | A66     | Marshall, H.G. 1975                  | A80     |
| Krishnaswami, S.K. & Kupchanko 1969 | A67     | Martin, A.E. 1971                    | C19     |
| Kuhnhold, W.W. 1972                 | A68     | Masnik, M.T., Stauffer et al. 1976   | A81     |
| Kumar, I.J. 1972                    | A69     | Matis, J.R. 1971                     | C20     |
| Kusk, K.O. 1978                     | A70     | Mattson, J.S., Mattson et al. 1977   | D28     |
| Kuznetsova, Z.I. 1967               | D21     | Mazmanidi, N.D. & Bazhashivilli 1975 | A82     |
|                                     |         | Mazmanidi, N.D. & Kovaleva 1975      | A83     |
|                                     |         | McAuliffe, C.D. 1977                 | B46     |
|                                     |         | McCauley, R.N. 1964                  | A84     |
|                                     |         | McCauley, R.N. 1966                  | A85     |
|                                     |         | McKee, J.E., Laverty & Hertel 1972   | B47     |

| <i>Author</i>                 | <i>Section</i> | <i>Author</i>                 | <i>Section</i> |
|-------------------------------|----------------|-------------------------------|----------------|
| McKenna, E.J. & Heath 1976    | B48            | Parker, P.L., Winters et al   |                |
| McKenzie, P. & Hughes 1976    | B49            | 1976                          | A111           |
| McKeown, B.A. & March 1978    | A86            | Parsons, T.R. & Li 1974       | A112           |
| McLee, A.G. & Wayman 1971     | D29            | Payne, J.F., Martins &        |                |
| Mechalas, B.J., Meyers &      |                | Rahimtula 1978                | A113           |
| Kolpack 1973                  | B50            | Pedroli, R. 1974              | F12            |
| Meijers, A.P. 1973            | C21            | Perry, J.J. & Cerniglia 1973  | B55            |
| Meijers, A.P. & Leer 1976     | C22            | Pessah, E., Loch & Macleod    |                |
| Meyerhoff, R.D. 1975          | A87            | 1973                          | A114           |
| Meyers, P. 1976               | C23            | Petrov, G.N. 1969             | B56            |
| Meynell, P.J. 1973            | E24            | Phillips, C.R. & Groseva      |                |
| Miles, D.H., Coign & Brown    |                | 1977                          | C24            |
| 1977                          | D30            | Pickering, Q.H. & Henderson   |                |
| Miller, J.W. 1973             | D31            | 1966                          | A115           |
| Mironov, O.G. 1969            | A88            | Pierce, R.H., Cundell &       |                |
| Mironov, O.G. 1972            | A89            | Traxler 1975                  | B57            |
| Mitchell, R. 1974             | A90            | Pochkin, Yu. N. & Massino     |                |
| Moore, S.F. & Dwyer 1974      | A91            | 1968                          | C25            |
| Morozov, N.V., Petrova &      |                | Pritchard, P.H. & Starr 1975  | B58            |
| Petrov 1969                   | B51            | Pritchard, P.H. & Ventullo    |                |
| Morozov, N.V. & Torpishcheva  |                | 1975                          | B59            |
| 1973                          | B52            |                               |                |
| Morrow, J.E. 1973             | A92            | Raisbeck, J.M. & Mohtadi 1974 | H11            |
| Morrow, J.E. 1974             | A93            | Rasmussen, D.V. 1976          | D32            |
| Morrow, J.E., Gritz & Kirton  |                | Reichert, J., Kunte et al.    |                |
| 1975                          | A94            | 1971                          | G5             |
| Mulkins-Phillips, G.J. &      |                | Rice, S.D. 1973               | A116           |
| Stewart 1974                  | B53            | Rice, S.D., Short & Karinen   |                |
| Muller, D. & Hellmann 1976    | A95            | 1977                          | A117           |
| Myers, L.H. 1976              | E25            | Robertson, B., Arhelger, S.   |                |
|                               |                | et al. 1973                   | B60            |
| Nadeau, R.J. & Roush 1972     | A96            | Rosenberg, D.M. & Wiens 1976  | A118           |
| Nauman, J.W. & Kernodle 1975  | A97            | Rosenberg, D.M., Wiens &      |                |
| Neff, J.M. 1975               | A98            | Saether 1977                  | A119           |
| Neff, J.M., Anderson et al.   |                | Rossi, S.S. & Anderson 1976   | A120           |
| 1976                          | A99            | Rossi, S.S., Anderson & Ward  |                |
| Neff, J.M., Cox et al. 1976   | A100           | 1976                          | A121           |
| Nelson-Smith, A. 1968         | A101           | Russell, F. & Gilson 1972     | A122           |
| Nemerow, N.L. 1978            | E26            |                               |                |
| Norrell, S.A. & Johnston 1976 | A102           | Sacherer, F.A. & Krassnigg    |                |
| Nuzzi, R. 1973                | A103           | 1970                          | A123           |
|                               |                | Saner, W.A. & Fitzgerald 1976 | D33            |
| O'Brien, P.Y. & Dixon 1976    | A104           | Saxena, J., Kozuchowski &     |                |
| Ogata, M. & Miyake 1973       | A105           | Basu 1977                     | D34            |
| Ogata, M., Miyake et al. 1977 | A106           | Seesman, P.A., Walker &       |                |
| Ogata, M. & Ogura 1976        | A107           | Colwell 1976                  | B61            |
| Osgood, J.O. 1974             | E27            | Seki, H. 1976                 | B62            |
|                               |                | Shaposhnikov, V.N., Kozlova   |                |
| Parekh, V.R., Traxler &       |                | & Arkad'eva 1968              | B63            |
| Sobek 1977                    | B54            | Shelton, T.B. & Hunter 1974   | B64            |
| Parker, B. & Barsom 1970      | A108           | Shelton, T.B. & Hunter 1975   | B65            |
| Parker, B.L. & Brammer 1975   | A109           | Shindler, D.B., Scott &       |                |
| Parker, B.L., Brammer et al.  |                | Carlisle 1975                 | A124           |
| 1976                          | A110           | Shuster, W.S. 1974            | A125           |

| <i>Author</i>                                    | <i>Section</i> | <i>Author</i>                               | <i>Section</i> |
|--------------------------------------------------|----------------|---------------------------------------------|----------------|
| Shuster, W.W., Clesceri et al.<br>1974           | E28            | Vogel, H.E. 1968                            | E33            |
| Snow, N.B. & Rosenberg 1975                      | A126           | Wakeham, S.G. 1976                          | C32            |
| Snow, N.B. & Scott 1975                          | A127           | Wakeham, S.G. 1977                          | D35            |
| Soto, C., Hellebust &<br>Hutchinson 1975         | A129           | Wakeham, S.G. 1977                          | E34            |
| Soto, C., Hellebust &<br>Hutchinson 1975         | A130           | Wakeham, S.G. 1977                          | E35            |
| Soto, C., Hellebust &<br>Hutchinson 1977         | A131           | Walker, J.D. & Colwell 1974                 | B70            |
| Soto, C., Hellebust et al.<br>1975               | A128           | Walker, J.D. & Colwell 1974                 | B71            |
| Spiker, E.C. & Ruben 1975                        | C26            | Walker, J.D. & Colwell 1975                 | B72            |
| Stanev, Ts. 1977                                 | B66            | Walker, J.D. & Colwell 1975                 | A144           |
| Stanley, S.O., Pearson &<br>Brown 1978           | B67            | Walker, J.D. & Colwell 1976                 | B73            |
| Starnes, P.K. & Brown 1976                       | C27            | Walker, J.D. & Colwell 1976                 | B74            |
| Stebbings, R.E. 1970                             | H12            | Walker, J.D. & Colwell 1976                 | B75            |
| Steele, R.L. 1977                                | A132           | Walker, J.D. & Colwell 1977                 | B76            |
| Stegeman, J.J. & Sabo 1975                       | A133           | Walker, J.D. & Colwell 1977                 | B77            |
| Straughan, D. 1977                               | A134           | Walker, J.D., Colwell &<br>Petrakis 1975    | B78            |
| Suess, M.J. 1976                                 | C28            | Walker, J.D., Colwell &<br>Petrakis 1975    | B79            |
| Swain, H.M., Somerville &<br>Cole 1978           | A135           | Walker, J.D., Colwell et al.<br>1974        | B80            |
| Takahashi, F.T. & Kittredge<br>1973              | A136           | Walker, J.D., Colwell et al.<br>1975        | B81            |
| Tatem, H.E., Cox & Anderson<br>1978              | A137           | Walker, J.D., Petrakis &<br>Colwell 1976    | D36            |
| Teal, J.M. 1976                                  | A138           | Walker, J.D. & Pore 1978                    | B82            |
| Thomas, R.E. & Rice 1975                         | A139           | Walker, J.D., Seesman &<br>Colwell 1975     | B83            |
| Thompson, S. & Eglington<br>1976                 | A140           | Walsh, F. & Mitchel 1973                    | A145           |
| Thueer, M. & Stumm 1977                          | C29            | Ward, D.M. & Brock 1975                     | A146           |
| Tischler, L.F., Elton & Ford<br>1977             | F13            | Ward, D.M. & Brock 1976                     | A147           |
| Toms, R. 1975                                    | C30            | Ward, D.M. & Brock 1976                     | B84            |
| Toms, R.G. 1971                                  | E29            | Water Research Association<br>1977          | B85            |
| Traxler, R.W. & Bernard 1969                     | B68            | Watkinson, R.J. (ed.) 1978                  | B86            |
| Trites, R.W. 1972                                | E30            | Westlake, D.W.S., Jobson &<br>Cook 1978     | B87            |
| Vandermeulen, J.H. & Ahern<br>1976               | A141           | Whelan, T., Ishmael & Bishop<br>1976        | B88            |
| Van der Waarden, M., Bridie<br>& Groenewoud 1971 | C31            | Whipple, W., Hunter & Shaw<br>1976          | H13            |
| Van der Waarden, M.,<br>Groenewoud & Bridie 1977 | A142           | Whipple, W. Jr., Hunter &<br>Yu 1975        | B89            |
| Van Loocke, R., De Borger<br>et al. 1975         | F14            | Whittle, P.J. 1977                          | C34            |
| Van Loocke, R. De Borger<br>et al. 1975          | E31            | Wilhm, J.L. 1965                            | E36            |
| Van Vleet, E.S. & Quinn 1977                     | E32            | Wilhm, J.L. & Dorris 1966                   | D37            |
| Vater, W. 1967                                   | B69            | Williams, D.E. & Wilder 1971                | A148           |
| Vestal, J.R., Federle et al.<br>1977             | A143           | Wilson, K.W. 1974                           | A149           |
|                                                  |                | Winters, K., Batterton &<br>Van Baalen 1977 | F15            |
|                                                  |                |                                             | A150           |
|                                                  |                |                                             | A152           |



| <i>Author</i>                             | <i>Section</i> |
|-------------------------------------------|----------------|
| Winters, K., Batterton et al.<br>1977     | A151           |
| Winters, K., O'Donnell et al.<br>1976     | A153           |
| Zajic, J.E., Supplisson &<br>Volesky 1974 | B90            |
| Zimmerman, W. 1970                        | A154           |
| Zitko, V. 1975                            | D38            |
| Zobell, C.E. 1962                         | B91            |
| Zsolnay, A., Maynard &<br>Gebelein 1977   | A155           |
| Zurcher, F. & Thuer 1978                  | C35            |
| Zweig, G., Nair & Compton 1968            | E37            |
| Zyul'kina, V. Ya. 1975                    | C36            |











UK& FB 80009

Freshwater Biological Association

Occasional Publication No.9

PETROLEUM HYDROCARBONS IN FRESH WATERS : 4

Desk Study and Bibliography / Jones, J.G.

Moorhouse, Pamela; Powell, Deborah L. 1980

**RESOURCE CENTRE  
INST. FOR ENVIRON'L. STUDIES  
UNIVERSITY OF TORONTO**





FRESHWATER BIOLOGICAL ASSOCIATION,  
AMBLESIDE, 1980.

TITUS WILSON & SON LTD.,  
KENDAL.